THE RADIO PATHFINDER

RICHARD·H·RANGER

To Mr. H. E. Batchelor

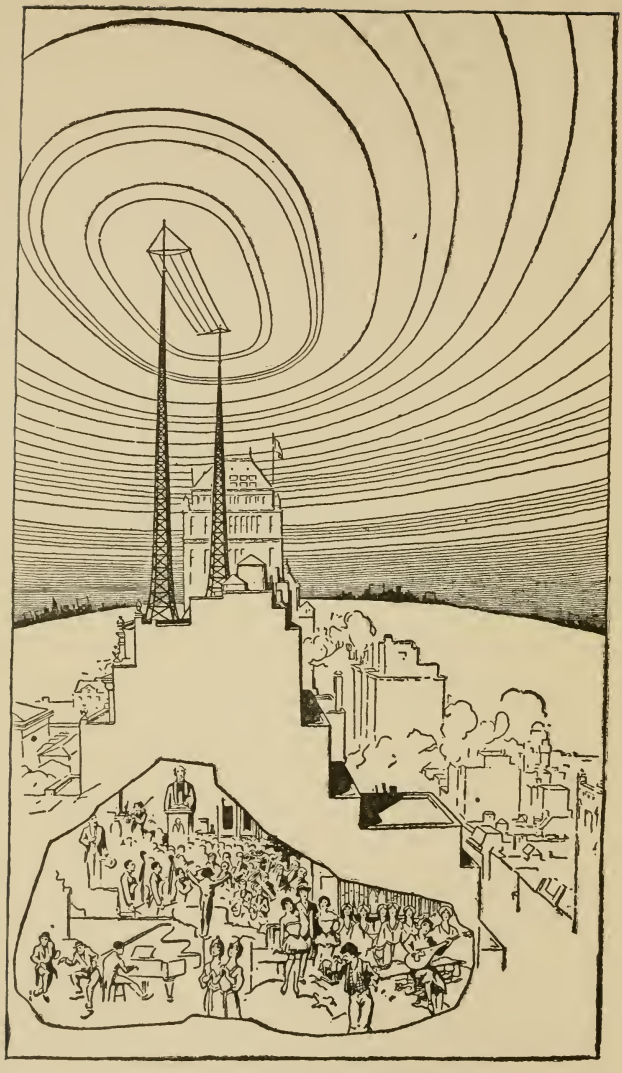
With best wishes of

Richard K. Hanger

January 1923

New York City.

THE
RADIO PATHFINDER



The Broadcast Transmitter

THE RADIO PATHFINDER

BY

RICHARD H. RANGER

LINE DRAWINGS

BY

THOMAS E. MONROE

GARDEN CITY NEW YORK

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1922

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Richard H. Ranger

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THE
RADIO PATHFINDER

THE RADIO PATHFINDER

I

RADIO-FAN

"Holla your name to the reverberate hills,
And make the babbling gossip of the air
Cry out."

—SHAKESPEARE.

ALADDIN rubbed his lamp. Wonderful vistas came at his call. Huckleberry Finn tried the same formula on a tin can with pretty poor luck. But to-day, with radio lamps, the radio-fan breaks into new worlds of imagination and reality. "There's music in the air" for those who know how to get it out!

Many are the wireless aerials which are now sticking their heads up over housetops. Each of these aerials leads into a little group of apparatus, some knobs to turn to select from the many programmes which are in the air; and in command, there is the radio-fan who has had the initiative to strike out into this wonderful art, which is still on the frontiers of its usefulness.

As the genii which come at his call, the radio-fan has the services of many little "electrons." These are the willing messengers which do the necessary work at the radio-transmitting station to start the music on its way; and which at the receiving station are ready to reproduce this into entertainment to be enjoyed by the radio-fan and his friends.

Credit is due the amateurs, who in making radio their hobby showed the possibilities in bringing all the world into their radio den. As they did this in the house, so this radio reception has taken its place as one more feature to make a house into a home.

As the amateurs soon came to talk glibly of the various parts of the radio sets, and in fact to make up many of the names themselves, so the radio-fan quickly learns the names of these necessary parts which direct the actions of these little electrons.

Electrons. As the name suggests, these little electrons are small bits of electricity. Like most servants, they will give best service when their idiosyncrasies are understood, and when their surroundings are most congenial. But they are most willing, and will do wonderfully well if given half a chance.

Plan of the Book. To assist the radio-fan in becoming a master of these electrons, this book will take up the steps in the order which the radio-fan will follow.

The first question is:

1. "What is this radio broadcasting?" (Page 4.)
2. "What happens at the radio-transmitting station?" (Page 8.)
3. "What happens at the receiving station?" (Page 14.)
4. "How does this sound get from the transmitting station to the receiving station?" (Page 20.)
5. "What equipment should I start with?" (Page 25.)
6. "How can I put up an aerial?" (Page 30.)
7. "What regulations must I observe?" (Page 48).
8. "What are the various parts of the set and how do they work?" (Page 54 to end.)

In the description of the sets and parts is given the possible troubles which may develop and their cures. This trouble "shooting" and general improvement of the effectiveness of the receiving station provides the fascination of achieving success in solving the radio puzzle.

II

BROADCASTING HISTORY

"Stentor, the strong, endued with brazen lungs,
Whose throat surpassed the force of fifty tongues."

Stentor Broadcasting at Troy

BROADCASTING started when Stentor spoke for Juno to rally the Greeks before the gates of Troy. Later, Alexander the Great is said to have had a large horn with which his hosts were called "eight Italian miles." This he properly called a "Stentorophone"; but the range of these was

nothing compared to the modern "radio broadcaster."

Marconi awakened the world to radio telegraphy in 1896. Fessenden first telephoned by radio in 1900, but it was during the concentrated development of the World War that radio telephony first became practical. Afterward, when all swords were being beat into ploughshares, this radio art became an adjunct to the large American telephone wire network. The American Bell systems with the Western Electric Company did a great amount of pioneer work. As one result, there is now the radio connection from the mainland near Los Angeles to the Island of Catalina.

At first, no one thought much of using this radio telephony for anything except communication as a substitute for wire connection. For this service, it has one serious drawback, which is that it shouts to all who may listen. All sorts of secrecy traps have been planned. During these investigations, the phonograph was, and still is, perhaps too convenient a tone source. The Western Electric Company used this in its tests from Deal Beach, New Jersey, and thus it was that speech and music were first broadcasted. At once, all along the Jersey coast, activity in radio reception rose rapidly. This effect showed that the lack of secrecy in radiophone communication might be its most important asset, which would carry

it out into its own special field—Radio Broadcasting.

Quick to realize this were the Westinghouse Company in East Pittsburgh, the Radio Corporation in New York City, the General Electric Company at Schenectady, and the American Radio & Research Corporation at Medford, Massachusetts.

Returns of the Harding-Cox election were sent out from East Pittsburgh. The first single event to be chronicled by radiophone with extensive preparations was the Dempsey-Carpentier fight. Round by round, to the tenth stroke of the bell, the progress of the battle was broadcasted from New Jersey.

Radio radiation quickly entered all social strata from church to police. From Calvary Church, East Pittsburgh, were first sent out Sunday evening services which reached hospitals and the homes of shut-ins—some of whom had not heard a choir

Stolen Autos Chased by Radio

for years. In the hub of New England, the police started to send out lists of stolen automobiles, some of which were quickly recovered by radio-fans.

Now it is said that the police are to have portable sets with them on their beats. By such means, the guardians of the peace will become tentacles, stretching out from a common nerve centre to hold in check even more effectively the machinations of the underworld.

All of this action has led up to the present well-recognized potentialities in radio broadcasting along organized lines. Every evening there is a definite programme at the service of the radio-fan. Those who are doing the transmission are companies interested in the sale of apparatus and newspapers or others for advertising and publicity. Even the Federal and State governments have begun the broadcasting of market and weather reports, particularly for the use of farmers.

Going into the future a little, it can be realized that this art is now going through rapid developmental stages, such as characterized the motion-picture industry. A new vehicle for entertainment has been realized. A new type of production managership will develop where the psychology of the radio-fan is appreciated, and programmes based on the utmost finesse of speech and music will be produced for character portrayal, education, and amusement. In contrast to the pantomime of the motion picture, this offers the magic of appeal to the ear.

III

RADIO TRANSMISSION

"Canst thou send forth lightnings, that they may go, and say unto thee: Here we are?"

—JOB.

AS FAR back as the fourth or fifth century B. C., there is this remarkable prophecy of radio transmission. In 1887, Edward Bellamy prophesied in his book, "Looking Backward," from the year 2000, that by touching "one or two screws" musical programmes of the day might be selected at will.

This situation has arrived sooner than he thought. Of course many refinements are to come, but the art is started, and the demand will bring the developments with a rush. Those who are already getting acquainted with the prodigy are going to have a most interesting time in watching and helping its growth.

Transmitting Station. The most conspicuous feature of the transmitting station is the aerial with its masts and the wires strung between, called

the antenna. This name antenna comes from the similarity of the structure to the antennæ or feelers of a bug.

Many have noted the number of wires necessary for wireless. The reason is that wires are the pathways of the electrons. They will run along a good wire with very little coaxing. Some wires are smoother paths than others; copper wire is good.

The function of the transmitting set is to send electrons up into this aerial or antenna, and then pull them down again. This back-and-forth motion keeps up very rapidly. Electrons are infinitely small; likewise they can travel at enormous speeds. It may take only a millionth of a second for a large group of these electrons to crowd up into the antenna and then crowd down again.

Still, there would not be much point to this rushing around unless something else happens. The electrons do not break away from the antenna into space, but an electron has a wide influence. When he moves it is known for some distance. He may be said to have quite a "sphere of influence." It is this far-reaching influence which makes them such valuable servitors. But they exercise this influence in a strange substance called ether.

Ether. Ether is a familiar word in radio. But it is hard to appreciate. Solid objects are easy

to understand. They can be seen, handled, moved. Liquids are a little harder to understand, but real difficulties begin with gases such as the air. We can blow air, and breathe it; but the most we know about air is what we are told rather than what we see for ourselves. Now, ether goes to the limit of being hard to appreciate as it is understood only by what is told.

Einstein has recently startled the world by telling it something it couldn't understand. The difficulty with our universe, as he shows, is that we are so much a part of it that we cannot observe its peculiarities. Our noses are too close to it.

In the same way ether is so close to us that we cannot appreciate it. It is everywhere. It is in us, through us, a part of us and everything we see. As there is no place where it is not, there is no line of demarcation. It is like a pungent smell which is unnoticed in a factory which it permeates.

But there are many things which take place through space where we know there is nothing material. We can see through empty space either outside the earth's atmosphere, or in an electric light bulb where only the slightest trace of air is left. So light seems to travel through some main substance which is left. In the same way, electric effects seem to be able to travel without the need of any of the ordinary substances such as air.

Scientists have been led to the convenient con-

ception of ether as the all-pervading medium which carries the light between here and the sun, for example, and everywhere else; and in particular which carries electric effects or radio waves through space. Radio waves are therefore ether waves. There is no connection between this ether of space and the liquid chemical also called "ether."

Production of Ether Waves. Electrons seem to have quite a hold on this ether. When an electron moves, there is a consequent wave in the ether. If there is an electric surge of a large number of these electrons up into the antenna, there is quite a splash in the ether. As there are these rapid surges back and forth in the antenna, there will be the consequent radiating waves sent out in the ether to travel in all directions.

Speed of Radio Waves. Like the electrons, the speed of radio waves is prodigious: 186,000 miles a second. This figure is the speed of light as well.

Instead of using miles, radio has grown up under the metric system of measurement. The metric system uses meters instead of feet, and kilometers (1,000 meters) instead of miles. A meter is 39.37 inches or a little over a yard. A kilometer is five-eighths of a mile.

Changing ether wave speed in miles to speed in kilometers gives a figure very close to 300,000 kilometers per second, or 300,000,000 meters per second.

Wave Length. If there was only one splash a second in this ether it is easy to see that the length of the wave would be this figure of 300,000,000 meters. But there is a lot more than one surge per second. There may be one million. If there are, the individual wave length will be only three hundred million meters divided by one million, which gives three hundred meters—about a fifth of a mile for a single wave.

The difficulty in appreciating the large numbers is only that we are not used to talking in these terms except for war finances. But three hundred meters is quite within reason, and all radio work is measured in terms of wave length in meters. This three hundred meters represents the actual distance from crest to crest of these particular ether waves in space, of which there are a million which pass a given spot in a second.

Each transmitting station is arranged to send these electrons up into the antenna, back and forth, at a fixed rate or frequency of surges per second. It therefore radiates the corresponding waves. The waves, when they have left the transmitting station, are identified by this wave length. In order to make as much room as possible for all the transmitting stations desired, a schedule of wave lengths has been prepared for the different types of services. Briefly, it may be said that amateur transmitters are supposed to send waves up

to a length of 200 meters. Ship radio traffic is mostly on 600 meters and 2,200 meters. Broadcasting is done on 360 meters by the commercial companies, and on wave lengths around 1,400 meters as well as 360 and 450 meters by the Government stations.

Continuous Waves. As long as the transmitting station is kept on, these electric surges will continue up and down the antenna, and the radio waves will be going out in space. They are radiated whether there is any sound being made at the transmitter or not. The radio waves themselves are noiseless. They are of the extreme high frequencies already mentioned, so that even if they were in the air, as sound waves are, they could not be heard.

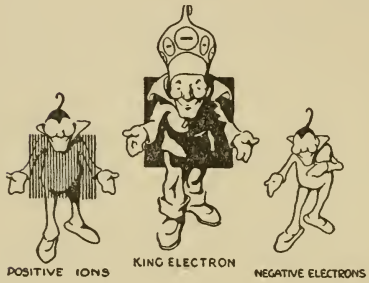
What these waves do at the receiving station will next be given, and then will be analyzed how these waves act as the carriers to great distances of much weaker sounds.

IV

RECEIVING STATION

"They hear a voice in every wind
And snatch a fearful joy."

—T. Gray.



In many ways the receiving station is a replica of the transmitting station except that everything is much smaller. Again there is the antenna. However, this antenna need only be a single wire stretched from the roof of one house to another, or to a tree or the barn. And there are the electrons.

Electrons are everywhere. It is only when there are more than usual in one place or they start to move that they become noticeable.

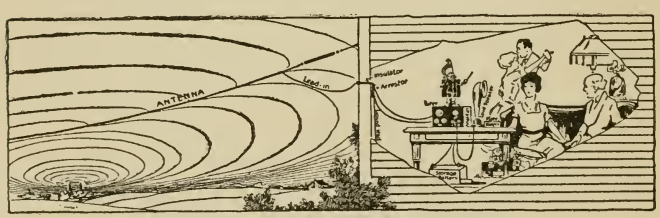
Positive and Negative Charges. The little electrons which cause all the commotion are little bits

of negative electricity. When there are more than the usual amount of them in any one place, they make a negative electric charge. The place they have run from will have less than usual, and it will therefore have a positive charge. The names of positive and negative charges are therefore largely relative, just like hot and cold. Hot is where there is more heat; cold is where there is less. The pioneer scientists happened to name the charge "positive" which has since been found to be the one with the least number of negative electrons. This idea of positive meaning less is a little awkward, but as long as it is appreciated that the active electrons are negative, there need be no difficulty. Furthermore, there is always a good chance that a new theory may come along. But this negative electron idea makes a very good working plan on which results may be achieved now.

Electric Current. Whenever there is a negative and a positive charge, there is a strong tendency for the two to balance up. This means an electron flow from the negative charge where there are more of them to the positive charge where there are less. Such a flow which may take place along a wire, or even as a spark in the air if the charge is sufficiently high, constitutes an electric current flow. Naturally, the pioneer scientists considered the current as flowing from the positive to the negative, which it is seen is just opposite to the negative electron

flow. To avoid confusion between the two ideas, we will consider only the electron flow in this book, which takes place from the negative to the positive charges.

Charges on the Antenna. The antenna at the receiving station stretches up in space. It connects through the receiving set to ground. "Ground" is a connection to the earth. Normally, there is an even distribution of electrons along the whole receiving system from antenna to ground. But the antenna stretches up into the ether where radio waves may pass. When these waves do arrive, the electrons in the receiving antenna are quite disturbed.



Ether Waves Strike Receiving Aerial

Suppose the crest of a wave comes along. This was made by a rush of electrons up into the transmitting antenna. When this high-pressure ether wave comes along, the natural reaction of the electrons in the receiving antenna is to get away from it to even things up. This they proceed to do by crowding down from the antenna into the receiving

set and into the ground. Immediately afterward, on the trough of the radio wave, they will all rush up again. This will continue as long as the ether waves keep up.

It is evident that here is the whole secret of wireless communication. A rush of electrons up into the transmitting station has sent a radio wave which causes electrons in the receiving antenna to rush down. The only remaining problem is to make the motion mean something in the way of words or music.

Penetration. These radio waves as they are in ether can go anywhere and through anything. The only thing that may happen to them is to get used up. Whenever they produce electron surges in a receiving antenna, a good portion of their energy in that locality is used up.

Now every bit of metal, such as the steel framework of a building, will act in the same way as a receiving antenna to the extent that electron surges in that metal will be produced. This is the only reason that it is difficult to receive radio signals in a steel building. As a matter of fact, there is always some energy still left. Very interesting results may be obtained with antennas completely enclosed in buildings, as will be explained later.

So radio waves go anywhere; and only lose their energy in the same way as waves on the water gradually decrease. These waves pass through

wood or glass quite readily. They pass through the air; but they are not part of the air. The air is only in the way as flotsam is on the ocean waves.

Tuning. In order to be able to select from the many radio waves which may be passing, tuning is necessary. This is done by adjusting the receiving set so that it swings electrically in step with the motion back and forth of the electrons. When the set is adjusted for a particular frequency, the electrons will get up only their maximum motion back and forth for the wave length which corresponds to this set frequency. Just how this is accomplished will be described for the various sets. As a matter of operation, however, the only thing necessary is to adjust the control handles of the receiving set until the desired signals are heard loudest.

Use of Received Signals. These electron surges in the receiving antenna have two difficult characteristics: they are very weak and they are extremely rapid. Their weakness requires that very sensitive telephone head-sets be used. The head-set consists of two telephone receivers on a band, with the connecting wires. The high frequency of the electron surges requires what is known as "Detection."

Detection. The rapid electron surges cannot possibly be heard individually. But their accumulative effect may be made to produce a much

slower result which can be heard. There are so-called crystal detectors and tube detectors. Both will be described in detail later.

Amplifiers. When it is realized that the radio waves travel out in all directions from the transmitting station, it is obvious that as the distance circle widens that the strength of the effects which may be picked up by any one receiving antenna must get quite weak. It is really very surprising that the effects do carry so far.

But it is too much to expect these waves to be able to produce enough noise from the receiving set to fill a room, as a phonograph. To accomplish this, "Amplifiers" are used.

Amplifiers strengthen the effect of the received signals enormously. They do it by using the weak received signals to set off much stronger power from an electric battery at the receiving station. Tubes are used for this which look like modified electric lights. This will be shown with the explanation of the construction of the tubes.

V

SOUND FROM RADIO WAVES

"My ears were never better fed,
With such delightful pleasing harmony."
—SHAKESPEARE.

RADIO waves are produced at the transmitting station. They pass very quickly to the receiving station. If the power at the transmitting station is turned on and off, the sounds produced at the receiving station would correspond. This constitutes the process in wireless telegraphy.

For telephony, something more is needed.

Tone. Tone consists of waves in the air produced by a vibration. Our ears are sensitive to the air pressure changes of the sound waves and give us the sensation of tone.

Tone Vibrations. Tone vibrations are nothing like as rapid as radio surges. For example, the bottom note on the piano has a frequency of about 27 cycles a second. That is, the string when struck makes 27 complete vibrations a second. This is so slow that it can almost be counted by watching the string vibrate.

Middle C on the piano has a frequency of 264 vibrations. For the highest note, the frequency is some 4,200 vibrations a second. The average speaking voice has a frequency of about 800 vibrations a second.

But there is a big difference between the same note struck on the piano or on the violin or sung by the voice. None of these are pure tones. As a matter of fact, nothing would be tamer than a pure tone. An example is the tuning fork—very serviceable for determining pitches, but never used as a musical instrument. All real musical notes consist of mixtures. These mixtures consist usually of the fundamental note with the additions of octaves above that note—one, two, three, or even more octaves above, to give the "timbre" to the tone. These octaves above are called respectively the first, second, third, etc., harmonics of the fundamental note. All of these which give value to the tone are below ten thousand cycles per second. It is not possible for the ear to hear much above this.

Unfortunately, it is not possible to make telephone head-sets economically which will respond to vibrations above five thousand cycles, but this is sufficient to give good musical quality appreciated by the ear.

Radio Frequencies. The telephone frequency is much below the usual radio frequency. High

frequencies have to be used in radio in order to get sufficient power into the antenna. If the antenna is small, only a relatively small amount of electricity as electrons can be sent up into the antenna each surge, so they have to be sent up a large number of times each second in order to produce any appreciable effect. This is why the amateurs have the short wave lengths which correspond to the very high frequencies. The longer wave lengths carry better, though; so for the high-power stations which transmit across the ocean, large antennas are used and relatively low frequencies—from fifteen to twenty thousand cycles.

This, however, is only two octaves above the piano scale, which shows that it is within reason. A remarkable boy soloist of the day has reached notes of this high order.

Broadcasting is done mostly on a wave length of 360 meters. This corresponds to a frequency of 800,000 cycles a second. This shows at a glance that there is no correspondence between the tone frequency and the radio frequency. The two are entirely of a different order as well as taking place in entirely different media.

Tone Controlled Radio. In order to transmit music, the radio waves must be controlled by the tone. In other words, the radio waves act as the carriers of the tone.

This control at the transmitting station consists in setting up a telephone transmitter called a microphone very similar to the one on every telephone which catches the music or speech produced in the radio studio. This microphone controls the output of the radio generator. The sound waves strike this microphone. When a high air-pressure wave hits the microphone, this may be connected to the radio generator so as to increase the power of the radiated waves. A low air pressure on the microphone would then decrease the power of the radiated waves. By this process, the radiated ether waves will follow in intensity the tone waves produced in the radio studio. This means that some groups of the radio waves will be of high intensity and other groups will be of low.

Tone at the Receiving Station. By their changes in intensity, the radio waves will carry the effect of the musical tones through space to the receiving stations. There is no further complication necessary at the receiving station. Instead of giving out telegraph clicks, the telephone head-sets will now respond to the changes in the radio waves which produce the electric surges in the antenna. Therefore, as these changes are produced by tone at the transmitter the head-set will give out a reproduction of the music from the radio studio.

These tones travel on such speedy radio wings that the two effects at the transmitter and the re-

ceiver are practically simultaneous, and the radio-fan gets the distinct impression that the music is being produced at that very instant for him, as in fact it is. Sound has been and will continue to be the best medium for conveying the fine gradations in meaning in speech as well as music; so here is set up a wonderful opportunity for extending personality and uniting all to a more mutual understanding by radio broadcasting.

VI

SELECTING A SET

"A brave kingdom to me,
Where I shall have my music for nothing."

—SHAKESPEARE.

WHEN broadcasting signals have once been received, the radio-fan has qualified. Improvement in these signals is relatively easy when there are definite signals to work with. Therefore, it is recommended that the first acquisition in the way of radio equipment be of a complete unit that will give signals. This set may be of the simpler type, which will give signals that may be heard with the telephone head-set. It will then be possible to add the units which will make it possible for all in a room to hear the signals. Those who wish to jump to this more finished type may get the sets complete with the horns.

Range of Sets. Standardization is still far from being realized in radio equipment; but the first thing that any one wants to know in purchasing such sets is what will work from an active transmitting station to the radio-fan's home.

Broadcasting ranges are dependent on the qualities of three factors—the broadcasting transmitter, the receiving antenna, and the receiving set. The following ranges are for one of the commercial transmitting stations rated as putting one-half a kilowatt of energy into the antenna. It is assumed that an outdoor antenna may be constructed of a length of about one hundred feet at a height of at least ten feet above surrounding buildings.

FOR HEAD-SET TELEPHONES

TYPE OF SET	RANGE IN MILES	PRICE
Crystal Detector	25	$ 20–$ 40
One Tube Regenerative	40	$ 45–$ 70
Three Tube Regenerative	60	$100–$150

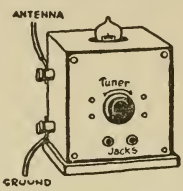
FOR LOUD SPEAKERS

Three Tube Regenerative	30	$125–$175
Four Tube Regenerative	45	$175–$350
Five Tube	60	$250–$400

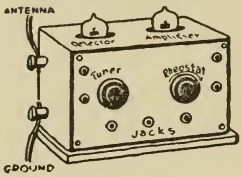
Principal Parts of Sets. Every set must have at least three characteristic parts: a "tuner" to select the desired wave lengths, a "detector" to change the rapid electric surges into audible signals, and a head-set or horn for hearing them. For working the horns, or loud speakers, a tube amplifier is

necessary. The tube amplifier takes the weak audio signal currents and builds them up to the point where they will work the loud speaker.

Tuner. The tuner has one or more knobs to adjust the set for the desired wave length. These knobs should move smoothly. The single knob tuners are quite satisfactory as well as simple, but a fine adjustment knob called a "vernier" in addition is a real advantage.

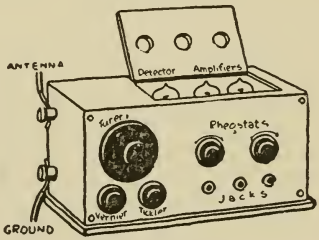


One tube set



Two tube set

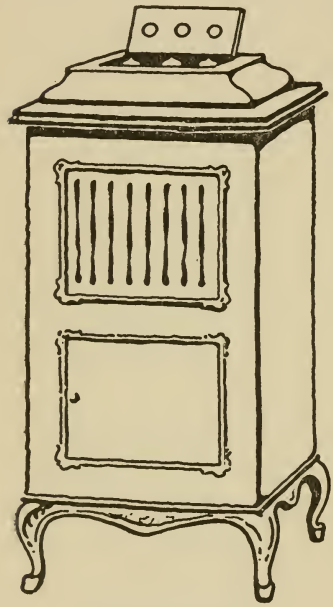
Detectors. Crystal detectors consist of a mineral crystal with either a fine wire in contact with it, or a spring pressure contact. The contact is adjusted on the crystal until the signals are heard best. This is a rather sensitive adjustment to make, but crystal detectors give good results over medium distances, and they avoid the complexity of batteries required on the tube sets.



Three tube set

TYPES OF SETS

Tube detectors are small electric lights of a special construction. These are lighted by storage batteries. New tubes are being put on the market which will light from dry batteries. In addition, a block dry battery is required called a "plate battery." Tube detectors give very uniform results, and require practically no adjustments other than the care of the batteries.



A Deluxe Equipment

Amplifiers. Amplifiers are made up of tubes similar to the detector tubes, mounted in appropriate holders and operated also by batteries. Usually, adjustments are provided to control the amount of current to light the filaments of the tubes. These controls are called rheostats. In place of rheostats, some sets are provided with glass "ballast lamps" which keep the current flow even through them into the amplifier tubes.

Head-Sets. Head-sets consist of two telephone

receivers on a head band. These telephone receivers should have a resistance of one thousand to eleven hundred ohms, making two thousand to twenty-two hundred ohms for the pair. The ohm is the unit to measure electric resistance to current flow.

Two head-sets may be operated off the same receiving set by placing the two in "series" so that the current enters one and then passes on to the other before returning to the set.

Loud Speakers. Loud speakers consist of horns with a telephone receiver at the base. With a good receiver and a suitable design of the horn to give out clear notes, the instrument is serviceable for entertaining a large number in a room.

Extra powerful loud speakers with extra amplifiers are also available.

With this brief survey of the equipment, the radio-fan is in a position to listen to the claims of the radio dealer, and very likely will be able with the aid of a radio amateur friend to select a serviceable instrument with which the start in radio reception may be made.

VII

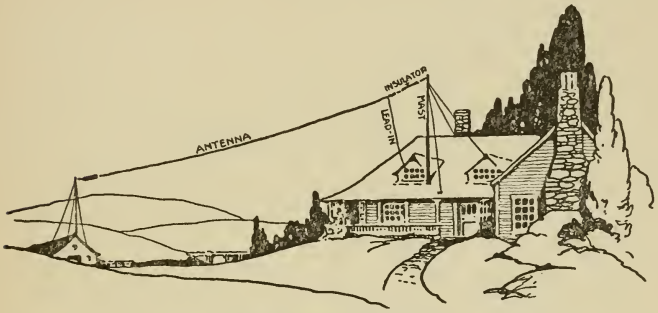
THE ANTENNA

"A little bird sat on a telegraph wire,
And said to his mate 'I declare!
If radio telephony comes into vogue,
We will all have to sit on the air.'"

A GOOD aerial or antenna is the first step toward success in radio reception. The cardinal points to be observed are these: Get a fair length of wire at a good height and as clear from all surrounding objects as possible. Have as few points of contact as possible for supporting the antenna consistent with good mechanical construction. A single wire antenna should be used. The antenna should lead into the receiving set in the house as directly as possible.

Selecting the Antenna Site. Make the location of the set and the antenna a joint problem. If possible, find a window which on the inside will give a good location for the receiving set, and which on the outside will start the antenna nicely. The antenna should go upward from the window to a point on or above the roof. If the roof is metal, this point should be at the top of a small wooden

mast of say ten feet. If the roof is wooden, the top point of the antenna may be fastened at the peak of the roof without any mast. The antenna should then have a straight-away run of at least one hundred feet. It is preferable to have it more up to a maximum of one hundred and seventy-five feet for receiving a wave length of three hundred and sixty meters efficiently. If this full length is obtainable, the antenna wire is only extended



The Antenna Location

to a length of one hundred and fifty feet. The remaining twenty-five feet is covered by a rope to hold the far end and thus keep it well away from the support. This reduces absorption of the energy.

Longer antennas may be used to advantage on longer wave lengths in the same proportion.

Antenna Equipment. The following equipment should be available for the antenna installation:

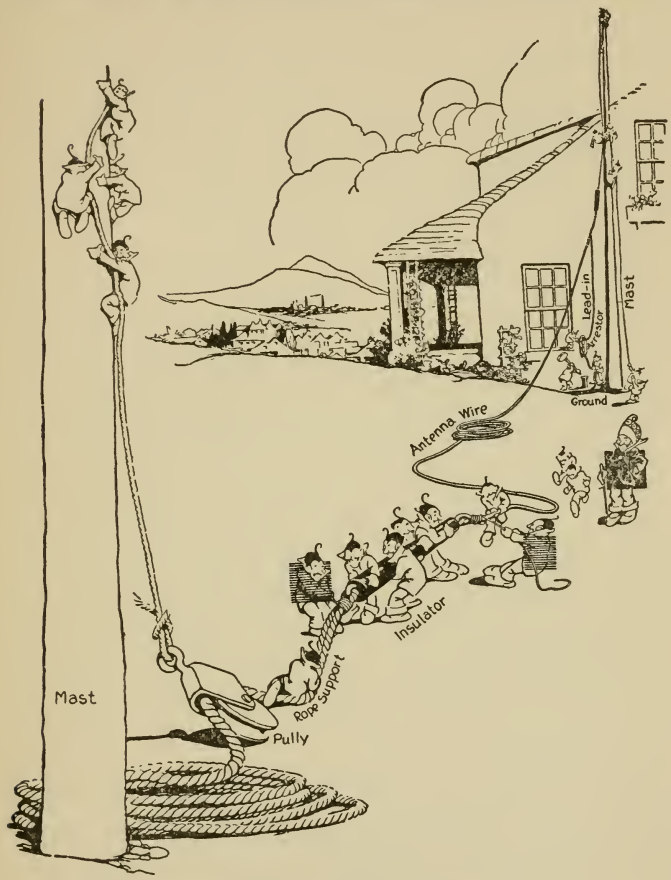
150 to 170 feet of antenna wire, No. 14 copper.
3 antenna insulators.
Lead-in bushing.
25 feet of rubber-covered wire, size No. 14.
1 lightning arrestor.
A ground switch (optional).
1 ground clamp.
50 to 75 feet of $\frac{3}{8}$ inch or larger hemp rope.
2 pulleys with screw hooks.
Necessary nails and screws.

The antenna wire may be solid, medium hard copper wire; or it may be stranded copper. Phosphor bronze wire or copper-clad steel wire is good where extra strength is desired in places where it would be bad to have the antenna ever come down, but these wires are much more difficult to handle, and are usually unnecessary.

Wire sizes go backward; the smaller the number the larger the wire. Number 11 wire has twice the cross section that No. 14 has.

The pulleys are placed at the high supports at each end. The hemp rope is run through the pulleys out to the antenna insulators. This makes it possible to raise and lower the antenna from below. The lightning arrestor or ground switch may be placed directly outside the window or directly inside the window where the antenna wire is led in. The lead-in bushing is put in a hole through the wall, or a board may be cut just the

width of the window, the bushing placed in the centre of this board and the board held in place by inserting it in the window frame above the upper



Putting up the Antenna

sash. The antenna wire is carried directly from the lightning arrestor or switch up to the first antenna insulator at the top of the building. The antenna wire is then continued on to the other insulator attached at the far support. The insulators are fastened to the antenna wire at such a position that the antenna will be drawn up nicely when the ropes are pulled up. The antenna wire should not be pulled so tightly that something is bound to give way in heavy weather.

If possible, the antenna should be one continuous piece of wire. If any joints have to be made, they should be made mechanically strong by twisting each of the ends to be joined around the straight part of the other wire. This makes a "Western Union" joint. This joint should then be soldered.

Soldering. Scrape the joint to be soldered to brightness. If a soldering iron is used, have it clean and heat the joint as well as the solder to such a point that the solder runs freely through the joint. With the joint hot, and just before applying the solder, place rosin on the joint to act as a flux. Apply the solder. Keep the joint still while the solder hardens.

If no soldering iron is available, an alcohol or blue gas flame is very satisfactory. This is used to heat the joint thoroughly and then the rosin and the solder are applied. A good-sized candle

flame may be used in an emergency, but this is apt to smudge the wire.

The Ground. The best possible ground should be obtained. A water pipe is usually quite satisfactory. However, it should not be necessary to run over twenty feet to a water pipe. If such is the case, it is better to use another thoroughly grounded metal such as the heating system or a gutter pipe which goes down into the ground. The gas pipe should not be used. The No. 14 rubber-covered wire should be used to run from the arrestor to the ground connection. The ground clamp is fastened around the pipe and the wire is fastened to the clamp.

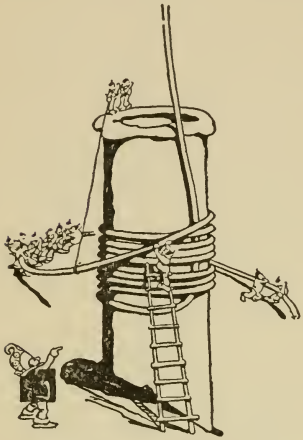
Cleaning Wire for Connection

Placing Rosin on Wire as "Flux" for Soldering

Heating Joint with Rosin and Solder Applied

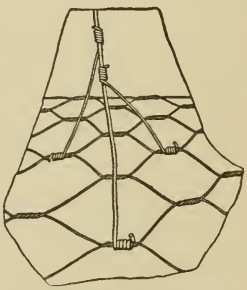
If no such ground system is available, a pipe may be buried three or four feet in the earth which should be moist. In place of a pipe, a metal plate two feet or so square may be used, or copper

chicken wire. A length of copper wire thrown in a well makes an excellent ground.



A Ground Pipe Connection

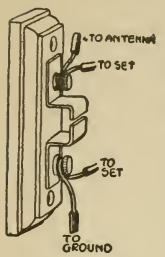
Lightning Arrestor. An approved lightning arrestor should be used. The antenna wire should not run anywhere near electric light or power wires. High voltage lines such as trolley lines, or those which supply the transformers on poles or buildings should be most carefully avoided. If only low voltage lines are approached, they should be kept at least four inches away and a fuse should be included with the lightning arrestor. The antenna wire is led directly to one side of the fuse—the side of the fuse farther from the spark gap of the arrestor. The lead in to the set is run with No. 14 rubber-covered wire from the other side of the fuse near the spark gap. The ground connection wire is led to the other side of the spark gap. A ground lead



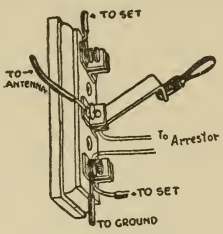
Chicken Wire Ground

to the set is also taken from the same point with No. 14 rubber-covered wire.

In case the fuse is not needed, the antenna is connected to one side of the spark gap of the arrestor, and the lead to the set is taken from the same point. The ground connections are made to the other side of the spark gap as before.

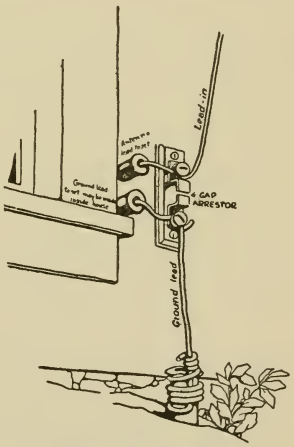


Lightning Arrestor



Ground Switch

Double Protection. Both lightning arrestor and ground switch may be used if desired to give double protection. In this case, the antenna is led to the middle or blade connection of the switch. The switch should be a double throw switch, so that the blade makes connection with one of the two contacts when it is thrown up, and with the other when it is thrown down. One side of the arrestor is connected to this same point. The upper switch contact is led into the set, so that when the



Arrestor Connection

switch is up, the antenna leads into the set electrically. The bottom contact of the switch is connected to the ground, so that when the switch is thrown down, the antenna is definitely grounded. The ground connection is made right through to the switch, then to the arrestor, and finally to the set.

By this arrangement the antenna is connected to the set when the switch is in the up position, and the lightning arrestor is always there for protection. When the set is not to be used, the switch is thrown down, which definitely disconnects the set from the antenna.

Lightning Hazard. It would be wrong to say that there is no possibility of danger from lightning, as no spot on the earth's surface is immune from the occasional chance flash. But certainly there is no more danger from an antenna than there is from a telephone wire; and if anything, there is certainly less danger than there is from high wooden structures. This is easily realized from the fact that trees are the worst offenders in attracting lightning. In fact, the antenna acts to a large measure as a lightning rod which will carry off to earth, through the arrestor or switch, the electric charges which are developed in the air and will thereby discharge them before they rise to such values as to be the cause of damage.

Apartment Houses. Modern cliff dwellings pre-

sent difficulties in the way of the radio-fan. But with his usual ingenuity he finds these are not insurmountable.

Indoor Antennas. If only about one-third of the range from the transmitting station is necessary for the particular receiving station, good results may be obtained by an antenna strung completely inside the building, provided it is not an all-steel building. If it is largely brick, the metal girders will not take up very much of the energy to shield the antenna within. The antenna should be a single wire strung for as great a distance as possible along the molding of the apartment. The wire should go as far away from the receiving set as possible. There is no advantage in doubling back.

For steel buildings, a single wire may be run along the windows of the apartment on the outside wall. If the wire can be kept six to ten inches away from the wall, good results may be expected.

If it is at all possible, however, it is better to run the antenna away from the building, possibly to the apartment on the next street back. Or the wire may be run up to the roof and then along the tops of the apartments at a height of about 10 feet for the full distance of 150 feet, if possible.

Bed-spring Antenna. It is impossible to overlook here the bed-spring antenna. In a brick apartment, local transmitting stations may be picked up in a receiving set connected only to a

water pipe for the ground and a brass bedstead for the antenna. No arrestors or switches are necessary on indoor antennas.

Loop Antennas. The aerial to catch the radio signals may be made in the form of a loop. Usually this consists of a three-foot square framework on which six to eight turns of wire are wound. It is obvious that these small loops cannot pick up much energy. It is not possible to get something for nothing in radio. Too frequently the opposite is true. So what is necessary is a large degree of amplification when using the loop. How this will be accomplished will be described with the process of high amplification. Also these decrease the effect of "static" somewhat.

Static. Static is that bothersome noise created by nature's many sending stations in the sky, which by small flashes signal to the receivers right on top of the desired programmes. Of course, this is more bothersome in the summertime, and particularly in the afternoons. Shutting out this static completely is still a problem for the radio-fans.

VIII

ARRANGING THE RECEIVING SET

"How sweetly did they float upon the wings
Of silence, through the empty vaulted night."
—MILTON.

ON THE inside of the window where the antenna is led in, the receiving set should be set up. If this is not the exact place where the signals are desired, it is possible to continue the antenna into the room or even into another room; but it must be realized that every bit of the added length to the antenna lead is wasting the energy. The matter will have to be a compromise between the desirability of locating the set conveniently, and having sufficient signals. Of course, if there is plenty of signal available, there need be no concern where the set is placed, relative to the antenna lead-in.

In general, it will be possible to locate the receiving set advantageously to the right of the window with the lead-in. American radio apparatus is usually designed so that the steps progress from the left to the right. In other words, the an-

tenna is connected on the left of the set, and the final output for the head-set or loud speaker is on the right. With the apparatus on the right of the window, this will bring the loud speaker into the corner of the room, which is a good place for it.

Table for Apparatus. An average-sized table should be available for the radio equipment. If a complete equipment is obtained at the start, no changes are to be contemplated. But a large number will start with the expectation of adding to the original set. For the latter, it would be well to select an older table, such that the occasional scratches which are bound to come will not make too much trouble.

The tuner will be set to the left of the table, leaving room to the right for the amplifiers and the loud speaker.

Connections. The wire from the antenna and the ground will be No. 14 rubber-covered wire. The antenna should be run in as much of an air-line as possible to the set. The antenna and ground wire should be kept well apart as they are run to the set—at least eight inches.

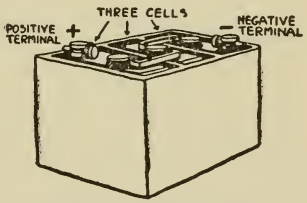
For the final run to the set from the wall flexible wire may be used. There is no heavy insulated single wire cord on the market as yet, so lengths of double conductor cord will have to be used. The heavy black silk insulated cord makes the best arrangement. The two wires in the cord are

bared at each end and the two twisted together to make one connection. Wherever the flexible cord is joined to the solid wire, the joints should be soldered and taped. The tape is ordinary tire tape wrapped over the soldered joint and over the insulation on each side of the joint to make the insulation of the wire continuous through the joint.

It is best to have as few points of fastening for the antenna lead-in as possible. Air is a very good insulator. In fastening the ground wire, and wherever necessary to fasten the antenna lead-in, insulated staples may be used.

All wiring should be as neatly done as possible. It prevents the chances of mistakes in connections and reduces unnecessary losses.

Storage Batteries. For those sets which require storage batteries, space will have to be provided. This may be directly under the table. Porcelain insulators should keep the battery from direct contact with the floor. No. 14 rubber-covered wire may be used for the battery connection, or some more flexible wire. In either case, the battery ends of the wire should be provided with strong spring clips which will connect solidly to the



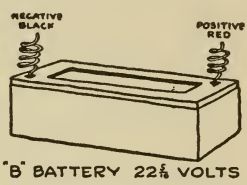
Six Volt Storage Battery

battery terminals. Care must be taken to connect the positive terminal of the storage battery, usually marked with a plus and painted red to the "plus (+) filament" terminal on the set. The negative, black, is connected to the "minus (—) filament" binding post on the set.

If the set is on the first floor, and there is a basement available, directly under the set, it is a very good plan to put up a shelf for the storage battery in the basement. The shelf should not be so high but what the battery on it may be inspected readily. To run from the set to the battery in the basement, the same No. 14 rubber-covered wire may be used. Better still, if some twin conductor lead cable can be obtained, a very fine installation may be made by running this lead cable through the floor from the set to the battery. The conductors in the cable should be No. 14 rubber-covered or larger. The lead sheath is readily removed in short sections at a time by slitting the lead with a knife. The lead sheath should be removed for a distance of about a foot and a half at each end of the cable to give fairly flexible connections to the set and to the battery. The lead cable may be fastened down by little strips of leather or tin with a screw through each side of the strip around the cable.

Plate Batteries. For tube sets, plate batteries are also necessary. These may be placed directly

behind the set. Usually it is possible to use the wire connections that come on the plate batteries. The red wire of the plate battery is positive and should be connected to the "plus (+) plate" terminal or binding post on the set; *never to either of the filament connections.* The black wire of the plate battery connects to the "negative (—) plate" terminal or binding post on the set. This negative may be the same terminal as the filament connection on some sets. If necessary, the wires may be extended with short pieces of No. 18 rubber-covered wire, or any insulated wire that may be available. The quantity of current taken from the plate battery is very small, so a small wire may be used.



Telephone Head-Set. Usually connecting cords come attached to the head-set. The free ends of these cords are attached to the binding posts marked for them on the set.

Tube sets usually have a plug for connecting the head-set. The free ends of the head-set cord are fastened in the plug, and then the plug is inserted in the "jack" in the set. The "jack" provides the connection in the set.

Cords similar to those for the head-set are necessary for connecting to the loud speaker.

Starting Operations. If the wires have all been

connected as indicated on the diagram of the set, it should now be possible for the radio-fan to start operations.

First, he looks to see that the antenna switch is up, if he has one. If the set is a crystal detector set, the next operation is to adjust the crystal contact until at least a slight rustling noise is heard in the head-set. Then by turning the tuner knob, whatever radio programmes may be going on should be heard.

If the set has tubes, the tubes should be inserted, the knobs controlling the lighting of the tubes should be started up from the minimum position. A rustling sound will be heard in the head-set when the tubes are working properly. Then the set is tuned, and the signals should be heard nicely. The tubes should never be lighted more brightly than is absolutely necessary to give good signals. Their life will be greatly increased by this care.

Tickler. Tube sets may be provided with ticklers. These act to increase the amplification. When the tickler is turned to zero, it is not acting. As it is turned on, a point will be reached where the signals are greatly increased. If this point is passed, the set will begin to howl, indicating too much tickler action. If this happens, it is usually necessary to decrease the tickler two or three points and then to build it up again carefully.

It is not well to use the tickler on the ragged

edge where it is apt to spill over. Also the quality of the output is not best at this point.

With an excessive amount of tickler to start with, weak signals may be identified and tuned in readily. The set is in tune when the howling goes to a low note. The tickler is then reduced to eliminate the tendency to howl, and the music or speech should be heard.

Caution. Excessive tickler makes a small transmitting station out of the receiving station which will radiate enough energy to disturb others in the neighbourhood who are trying to listen. Therefore. to keep the tickler definitely below the howling point should be the "Courtesy of the Ether" among radio-fans.

IX

INSURANCE REGULATIONS

"Fear no more the lightning flash,—
Nor the all-dreaded thunder stone."

—SHAKESPEARE.

RULES for the installation of broadcast receiving stations are still in the formative stage, but the general lines are pretty clearly indicated. The person to be satisfied is the Insurance Company which has the insurance on the house. They should be advised of the proposed installation, and they will then furnish a permit after they are satisfied with the workmanship.

The following general rules indicate good practice, and every installation should measure up to these requirements at least.

Neatness is the first and most important requirement. If the wires are straggling around the set, trouble is bound to come up.

A lightning arrestor may be used as a protection to reduce lightning troubles, or, as has been described, a ground switch may be added to give practically 100 per cent. protection. The

arrestor must be of an approved form. The approval is given by the National Board of Fire Underwriters.

The antenna, which must be No. 14 B & S gage copper wire, must be put up in such a manner that it cannot come in contact with electric power wires. Joints in antennas, which should be avoided, if necessary should be soldered or made by splicing sleeves, such as the telephone companies use. An insulated bushing, such as a porcelain insulator, must be used to bring the antenna lead wire into the building. A hole may be drilled in a window pane for this purpose by a glass cutter.

The Ground. The ground wire should be No. 14 or larger B & S gage copper wire, insulated or bare. It should be run as directly as possible from the lightning arrestor ground switch to a water pipe or the radiator system. Gas pipes must not be used for grounds. A ground clamp should be used to fasten the ground wire to the water or other pipe. The ground wire should be fastened securely along the wall or mop-board, so that it will not be displaced or broken.

Copper-clad Steel. Approved copper-clad steel may be used in place of copper and may be as small as No. 17 B & S; but No. 14 is not much more expensive, so is recommended.

Old Rules. The old rules were prepared largely

for transmitting stations. Their requirements are not necessary for the present small broadcast receiving stations. For example, many of these used to require that the arrestor be outside of the building, and that all wire be kept a distance from the wall. Now the arrestor may be inside or outside the building, and the wiring need not be kept away from the wall. Of course, for radio work, it is absolutely necessary that the antenna be insulated from contact with the wall by good insulators, but the ground wire may be fastened directly to the wall with insulated staples.

Avoid High-voltage Wires. Antennas should be so placed that they are in no danger of ever coming in contact with electric power wires of over 600 volts or of trolley or feeder wires, by not being run over or under them. Ordinary light wires should be kept well away. The regulations stipulate four inches outside of buildings and two inches inside; but it is far better from the radio point of view to keep them at least three feet away, as they may be a cause of noisy interference.

Power Connection. If any permanent arrangements are made for connecting to the lighting circuits for charging the storage batteries, such insulations must come under the regulations of wiring in houses. If only a flexible cord with

attachment plug is used for this work, no special inspection will in general be necessary.

The whole question comes down to one of getting permission from the fire insurance company to make the installation, and the inspection will be made after the installation is completed.

X

INTERMISSION

"*An ampler ether, a diviner air.*"
—WORDSWORTH.

A GENERAL analysis of the broadcast system has been given. It now remains to show exactly how each part fulfills its mission.

For the radio receiver there are the following missions of the respective parts:

1. The antenna and ground together act to collect the radio energy from the ether waves.

2. The tuner adjusts the antenna system to resonate with the desired signals only.

3. A detector takes the energy brought into the tuner by the antenna and transforms it into electric currents which will work a telephone receiver head-set.

4. Tube amplifiers build up these electric currents for the head-set to such an extent that they will work a loud speaker.

5. The head-set transforms these electric currents into sound.

6. The loud speaker will send out this sound in such volume as to fill a room.

7. The storage and plate batteries supply the driving power to the tube sets.

Each of these parts is either a channel along which the electrons move or it is the driving force which makes them move. The radio-fan will do well to direct their motions to get the very best results in the way of entertainment coming from the head-set or loud speaker.

XI

ANTENNA AND TUNER

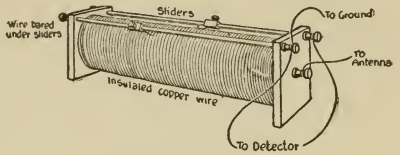
"Hark!—Music i' the air—
Under the earth.—It sings
well, does it not?"

—SHAKESPEARE.

ANTENNA, tuner, and ground act really as one continuous system to pick up the desired signals from the ether waves. In this series, the antenna comes first, then the tuner, and finally the ground. This combination must resonate with the desired incoming signals in order to build up a large swinging motion of the electrons in response to the desired signals. Although they move very quickly, still it takes an appreciable time for the electrons to move in quantity over this path. If they move over this path in just such a time that they surge down through to the ground and then back again just in step with the oncoming ether waves, then we get the maximum response to these particular waves.

The antenna and ground connected alone without any tuner have a definite time period of their

own. Electrons will press down the antenna into the ground and back again in a time period determined by the length of the antenna and its height from the ground. But this period would be fixed for any one antenna so it would not be possible to adjust for a wide range of wave lengths. To provide this most convenient adjustment feature, the tuner is added.

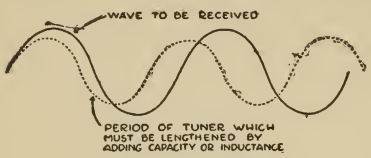


Slide Wire Tuner

Tuner. The tuner may consist only of a coil of wire. This coil of wire may be wound with insulated wire on a paper cylinder. The insulation of the wire is scraped off in a line down the turns, so that a sliding contact may be run along these turns of wire. As the slider runs along, it makes contact with the wire at various points. If the antenna is brought into the top of such a coil, and the ground is connected to the slider, it can be seen that this provides a means of lengthening the antenna ground circuit by adding turns of the coil to the circuit.

The antenna alone has a "natural" time period, such that it will resonate for waves about four times its actual length. In other words, an antenna one hundred feet long would resonate to a wave four hundred feet long. This is about one

hundred and twenty-five meters; but by adding turns of the coil to the circuit, this period may be lengthened up to a value of three hundred and sixty meters and more.



Tuning to Waves

Electrons are everywhere throughout this system. They are in the antenna, in the coil, and in the ground. Normally, there is an even distribution of them over the whole circuit. But when the wave comes along, they rush up and down from the antenna to the ground; and in consequence they are also induced to move in the coil by the onrush of those down from the antenna. Such a coil is called an "inductance."

Inductance. Electrons will move readily along a wire, but they move with great difficulty through insulation. This characteristic is what determines whether a substance is a conductor or insulation. In order to make the electrons do useful work, they must run along the desired path and not get out of it. The conductor, as the wire, lets them travel, and the insulation keeps them where they should be. The coil of wire as an inductance has these two essential features: the copper conducts the electrons, the insulation wrapped around the wire keeps them to this path.

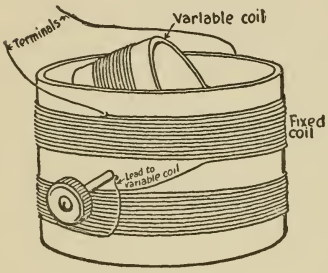
There are electrons through the coil. Other electrons come rushing into the coil. This makes all of them move. Naturally, this slows up the progress, but it also makes more of them moving once they get started. So adding inductance slows up the period of the antenna circuit.

As a matter of fact, the wire in an inductance coil is more effective in increasing the period than the same amount of wire would be if strung out in a straight line. The coil of wire cannot be considered as a copper spiral through which water flows. As it will be remembered, electrons when moving are more than just little particles. They have quite a wide influence, so when an electron starts moving in a coil of wire, all the other electrons in that coil know of it at once by the ether breeze which strikes them. They resent this by trying to move against the breeze and back through the wire in such a direction as to oppose the motion of the wayward electron. This all tends to keep the coil in a state of electric rest; and the surge of electrons coming down from the antenna has all this opposition to meet. But once they have met it and won, the consequent surge of all the electrons carries the movement on. This opposition is not in the form of resistance. It is more like the mass of a line of billiard balls, hard to start but which takes up the energy and carries it on once they start. So a small coil forms

a very convenient means of lengthening the antenna circuit at will, so that it will resonate to various ether wave lengths.

Variometers. Instead of the long coil with the slider, another form of inductance in a very compact space is the variometer.

It has just been shown that the electrons in one turn of a long coil have an effect on the electrons in all the other turns such as to oppose changes in electron motion. But this is because all the turns are wound on in one direction. If a coil were wound with say twenty turns in one direction and then the wire was turned around a peg in the cylinder on which the coil was wound, and then twenty more turns were wound in the opposite direction, the effect of electrons in one half of the coil on those in the other would be quite different.



A Variometer

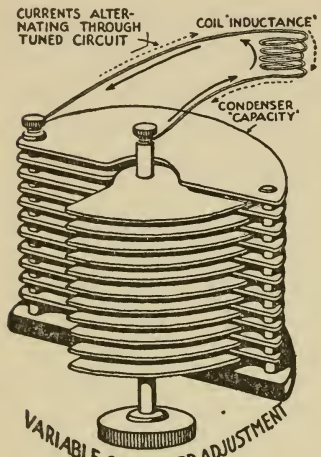
Now, if an electron started to move in one half the coil, the ether breeze on the electrons in the other half would tend to make them oppose this motion as before as far as going around the coil turns is concerned. But as the two halves are wound in opposite directions, this would make the

second electrons move out their end of the coil instead of bucking the first electron that started the trouble. The net result is that there is very little inductance to a coil so wound.

Instead of winding the two halves of such a coil on one cylinder, one is wound on a smaller cylinder than the other so that it may be placed inside of the other. So located, and with a flexible connection between the two halves, the inside one may be rotated inside the larger. If it is in the position where the windings are in the opposite direction as just described, the whole combination has a minimum inductance. It may be rotated around, however, to such a position that the windings progress in the same direction. In this position, naturally the inductance will be a maximum, as it corresponds to the single continuous coil first described. Therefore, by rotating this coil, a wide range of inductance values may be obtained very smoothly. Such a device when inserted in the antenna circuit provides a nice way of varying the period of the complete circuit. This type of inductance is called a variometer.

Condenser. Another nice way of varying the period of an antenna circuit is by means of a "condenser." If two metal plates are brought near each other in such a manner that they just do not touch, they make a condenser. Their action is as follows: If a large group of electrons

surged on to one of the plates of such a condenser, it is natural that the electrons on the other plate would run away. This is exactly what they do.



Variable Condenser

But there is no actual transfer of electrons across the space which separates the two plates. If the antenna is connected to one of these plates, and the other is connected to the ground, the electrons surging down from the antenna will give a negative charge to the first plate on which they pile up by their number. The plate from which those opposite are driven away will be positively charged, as it will have such a deficiency of these negative electrons.

If the plates of the condenser are large enough, this motion of electrons on to one plate and away from the other will be so easily realized that it will act just as if there were no condenser there and the wire was continuous from antenna to ground. However, if the plates are small, the electrons surging down from the antenna will pile up on the first plate very quickly and squeeze back so much

on the others trying to come down that only a few will get on the plate. Likewise, only a correspondingly few number will run away from the opposite plate. This whole operation will happen much more quickly, however, than if the plates were large. Therefore, the period of the antenna circuit with the condenser added is much shorter than before. So, adding a condenser in the antenna circuit shortens the period of the antenna to make it resonate or tune for shorter wave lengths.

Instead of cutting the condenser plates to size, as is done for a "fixed condenser," the effective condenser surface may be varied by sliding one plate over the other. The plates must never be allowed to come in contact, as then all condenser action is lost as a straight through metal connection is made. By varying the relative surfaces of the condenser plates with respect to each other, a wide range of condenser sizes may be realized. This is done conveniently by making the condenser in the form of semi-circular plates. Several such plates are fastened together to make one side of the condenser, and several more are mounted together on a shaft for the other side so that they may be rotated inside of the others. The two sets mesh with each other. It requires nice mechanical construction to insure that none of the opposite plates ever come in contact. As the

movable plates are rotated in mesh with the others, the effective condenser surface is varied. The effective surface is that portion of the two sets of plates which are quite close to each other. This condenser variation gives a smooth adjustment of the antenna circuit period to cover a large number of wave lengths.

To correspond with the word inductance, there is the word "capacity," which means this characteristic of the condenser to hold electrons. The larger the condenser, the greater its capacity; also the greater the capacity, the greater the antenna period, and the greater the wave length for which it tunes.

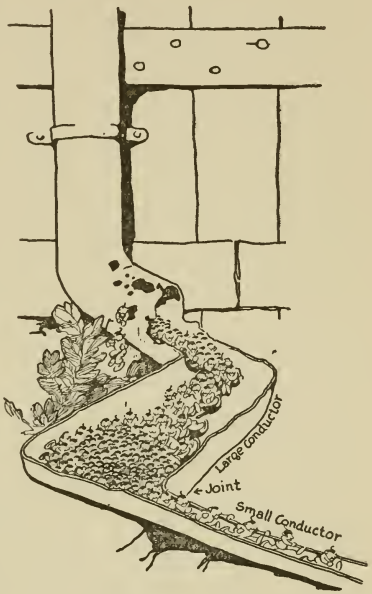
Tuner Design. These two factors of inductance and capacity give the radio-fan two fine means of controlling the surges of the electrons in the antenna circuit. Either one or both may be used.

Some sets are made of the slide inductance. The radio-fan may make one for himself. It requires a rather nice alignment so that the slider will always make contact with the turns as it is run down the coil. Square rod is the best for the slide. The wire should be double cotton covered, and of a size of No. 22 or larger if there is not too much of a desire to make a very compact set.

The smaller the wire used the greater the resistance. This is really resistance which uses up the energy of the electron surges without any

benefit in getting it into signals. There is no need, however, in using wire larger than No. 18. A mailing tube soaked in heated paraffin makes an excellent cylinder for winding the coil.

Variometers are perhaps more readily made at home. Two tubes are obtained from two to three inches in diameter, one of which will rotate in the other. Some wooden dowel rod makes a convenient support for the rotating half. The assembly should be tried before winding the wire. Twenty turns of wire on each of the cylinders will give a range of adjustments generally serviceable for the radio-fan. Of course, space will be left in the centre of each winding for the rod. A small groove may be cut in each end of the dowel rod at the bearing points to provide a place where the two wires from the centre coil may be brought out. One of these wires



Principle of Resistance

from the centre coil is connected to one end of the fixed coil winding. This leaves a free end to each of the windings, so that the antenna may be connected to one and the ground connected to the other.

Spider-Web Inductances. Other forms of inductance on the market are the spider-web coils, which, as the name suggests, consist of an odd number of radial arms to support the wire wound in cobweb fashion between the supports.

Honeycomb Coils. With machinery similar to that which winds string into a ball, coils of wire are wound to form compact and efficient inductances.

Any of these styles of coils may be mounted so that two of them may be moved close together or farther apart to vary the value of their combined inductance.

Types of Condensers. Condensers may be "fixed." In this case they usually consist of two sheets of tin foil cut to the appropriate size and separated by paraffin paper. The whole outfit is then rolled into a compact unit and put into a metal container. Two leads are brought out of the container connecting one each to the respective pieces of tin foil.

Variable Condensers. The usual form of variable condenser is that of the semi-circular plate segments described above. A convenient size for the radio-fan is of a diameter of about four inches with about twelve plates on each side.

Die-Cast Condensers. These variable "air" condensers are now made in very compact form by die-casting the plate segments. This permits very accurate manufacture, with very small clearance between the plates and consequent compactness.

Mercury Condenser. Another interesting type of variable condenser is the Mercury condenser. This consists of a metal container lined with mica insulation. The metal container forms one plate. The other plate is the mercury which, as the container is rotated, flows in between the insulation. Such a condenser gives a wide capacity variation in a small space.

Tuner Assembly. Tuners are made of combinations of these inductances and capacities. A good simple arrangement consists of both inductance and capacity. The inductance is in the form of a variometer to give the smooth variations. To give two distinct ranges to this smooth variation, two fixed condensers are added. The circuit consists of antenna to one condenser, to variometer, to ground. The first condenser used shortens the tuning period to one series of values as the variometer is varied. The other condenser has a different value so that when the antenna is connected to it in place of the other and then leads to the variometer and ground, a different series of wave lengths may be selected.

Usually the two series of wave lengths overlap slightly so that a continuous selection of wave lengths may be obtained with the two alternately. By using both condensers strapped together and connected to the antenna, yet another set of longer wave lengths may be tuned to.

Other tuners consist of variable capacities and fixed inductances. The variable capacity may be the variable "air condenser" with the metal semicircular segments. The inductances may be any of the coil types. Again, it is usual to have two or even more values of fixed inductance which may be selected at will and which in conjunction with the variable capacity will give a wide range of wavelength adjustments. As before, the antenna is connected to the condenser, thence to the inductance, and thence to ground.

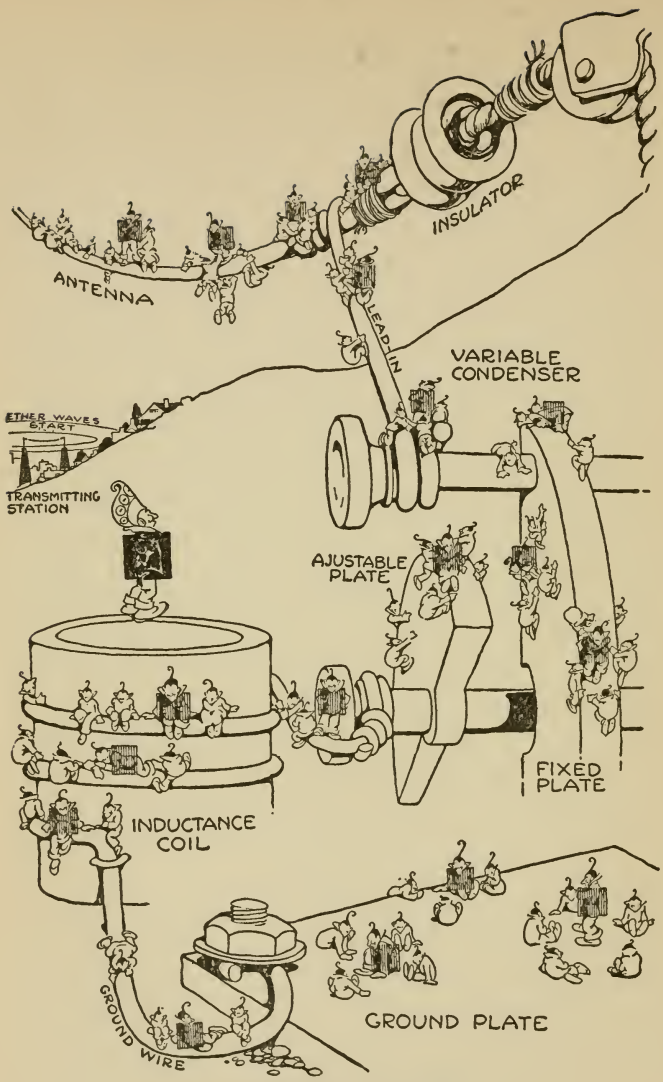
As the final word in tuner design, are the sets with both variable inductance and capacity. Both the variable elements are mounted on the same shaft. A wide range of adjustments with a single motion may be realized from such a combination.

Vernier Condenser. In order to provide finer adjustments in tuning, it is advisable to have a very small condenser in addition to the larger one. The small one is called a "Vernier" condenser as it gives a very fine shade of capacity values around the value the larger capacity is given.

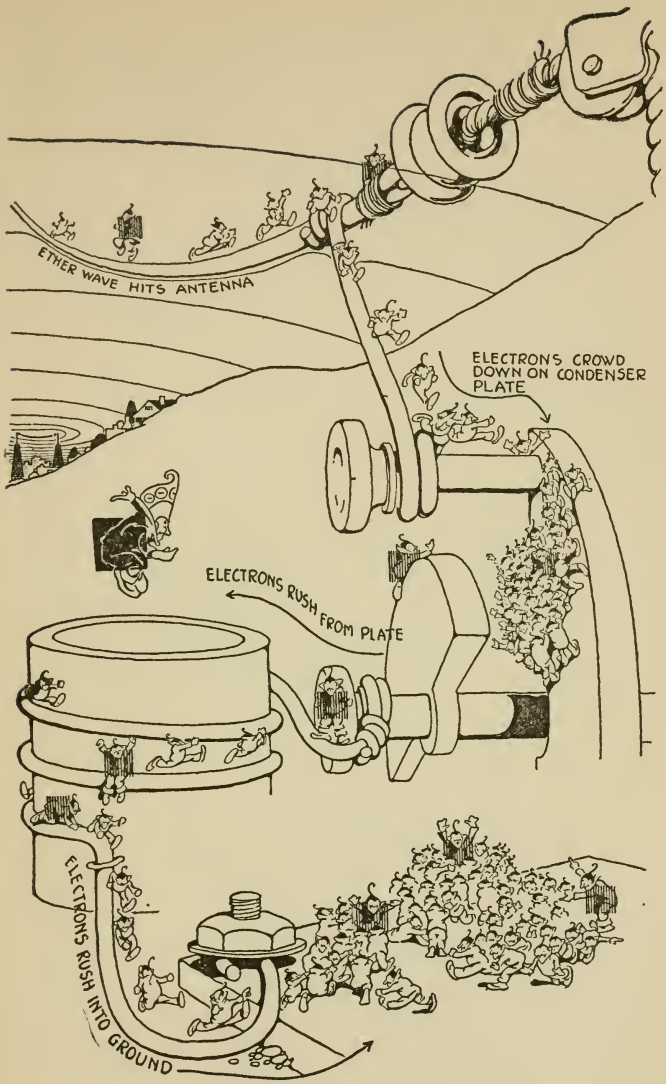
Electrons in the Antenna Circuit. Now let us picture what happens to the electrons in the complete antenna circuit, which it will be assumed consists of the antenna, a variable condenser, a fixed inductance, and the ground.

With no ether waves passing, there is an even distribution of electrons throughout the whole circuit. This gives the average or "zero" charge to everything. Now, along comes an ether wave. This means to the electrons up on the antenna the same thing as a large number of electrons charging them. There is no direct motion of electrons through space from the transmitting station to the receiving station. The ether waves alone carry the effect. At any rate, the electrons out on the antenna try to rush down and crowd on the top plate of the variable condenser.

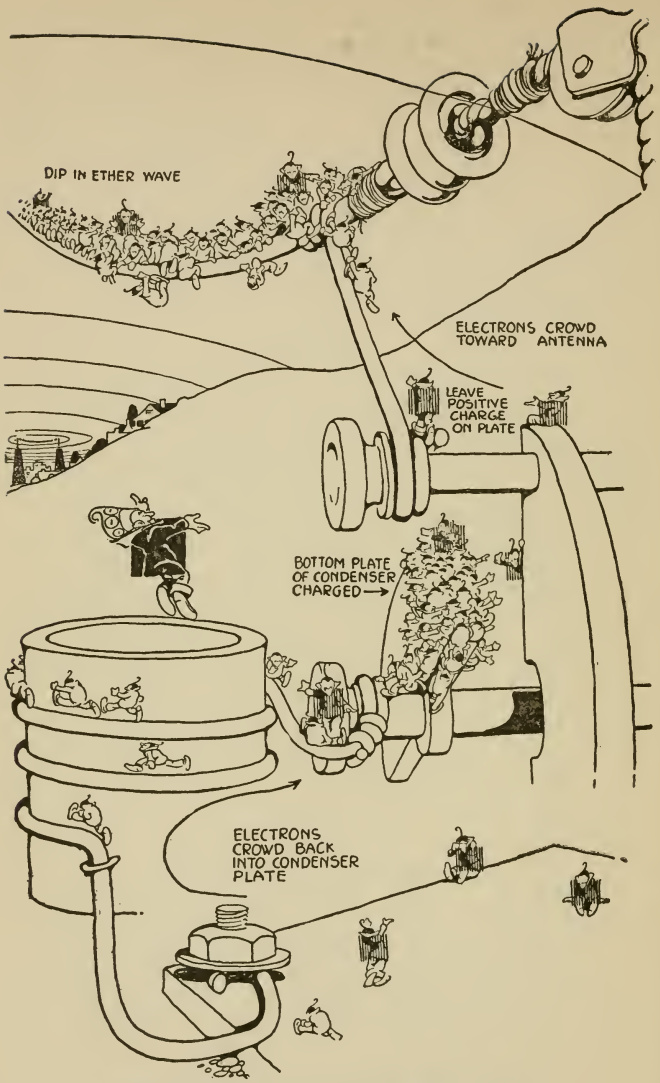
This onrush looks very real to the electrons on the other plate, so they rush away into the inductance coil. It takes them a little time to get all the electrons to move in the coil; but they do, and then they all rush down the ground lead into the earth. When they get all over their excitement, they find that there were no electrons coming, after all. Now that the influence is gone, they look back and see the positive charges that have been left alone. They start back, and like sheep they develop this into a stampede in the other direction. If the time that it takes them to start back is just



The Zero Hour in Tuning



The Crest of an Ether Wave Arrives


DIP IN ETHER WAVE
ELECTRONS CROWD TOWARD ANTENNA
LEAVE POSITIVE CHARGE ON PLATE
BOTTOM PLATE OF CONDENSER CHARGED
ELECTRONS CROWD BACK INTO CONDENSER PLATE

The Swing-back on a Dip in the Ether Wave

right for the dip of the wave in the ether which now comes along, all the better; and they rush like everything back through the coil on to the bottom plate of the variable condenser. Those on the other side of the condenser have already reasoned likewise, and so out they have rushed on to the antenna. If the condenser value and the inductance value are just right to give the right electron time reaction to these surges, which just fits in with the ether waves, a real swinging motion is set up which develops very strong values in the receiving antenna circuit, considering the weak ether impulses which start it.

Here is the whole principle of tuning, and the radio-fan has at his disposal the means for varying the lines of travel of these electrons in his set in such a manner as to build up their surging motion to a peak value for the radio signals he desires.

XII

CRYSTAL DETECTORS

"Why all this rushing about of electrons? How does it produce any effect in the telephone receivers?"

—Radio-fan.

This radio work involves so many new ideas that it is hard to keep them all in mind and see that they all work forward to the desired result of real entertainment in the home. But they all contribute their part; and the next to be analyzed is the detector.

It is now understood that when, for example, a 360 meter wave hits the receiving antenna system electrons surge back and forth in the tuner, and most rapidly, too. Some eight hundred thousand times a second for this wave length. Now, this is altogether too fast to be appreciated by any usual instrument, so the "detector" is necessary.

Purpose of the Detector. A detector must translate the rapid electron surges into electric currents which will operate a telephone receiver head-set.

To do this, currents which change only on an average of 800 times a second to correspond to ordinary speech must be produced.

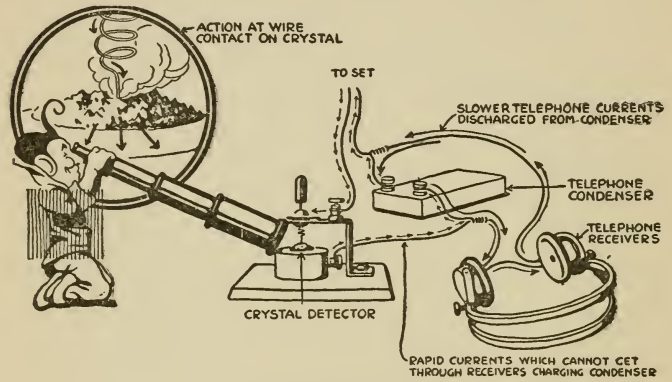
This the detector does by taking as much of the electron energy as it can get and producing ordinary electric current from it. Then as the electron energy varies with changes in intensity of the ether waves, this ordinary current will change. It is ordinary current changes which produce the sound in telephone receivers, as will be shown later. There is no difference between the rapid electron surges and ordinary electric current except the rates at which they change. Electrons to work a telephone receiver must continue in one direction through the receiver for a time of the order of one eight-hundredth of a second. This is quite slow compared to the surges in the antenna.

If it could be arranged that the electron surges continue to hammer away in one direction, their total effect would be a general motion in one direction.

Crystal Detector. The crystal detector does this by being a trap for electrons. The combination of a crystal and a fine wire point acts as a trap to let electrons through in only one direction. With the galena crystal and the steel wire this trap works to let the electrons pass from the wire down through the crystal, but not back again.

The tuner is the source of electron energy when

the ether waves are working. This energy may be tapped by putting two wires between two points where, on the limits of the electron surges, there is a piling up of the electrons. Two such places are across the condenser. Another two are across the inductance. When the electrons all rush up into the lower condenser plate, for example, the


ACTION AT WIRE CONTACT ON CRYSTAL
TO SET
SLOWER TELEPHONE CURRENTS DISCHARGED FROM CONDENSER
TELEPHONE CONDENSER
TELEPHONE RECEIVERS
CRYSTAL DETECTOR
RAPID CURRENTS WHICH CANNOT GET THROUGH RECEIVERS CHARGING CONDENSER

The Crystal Detector

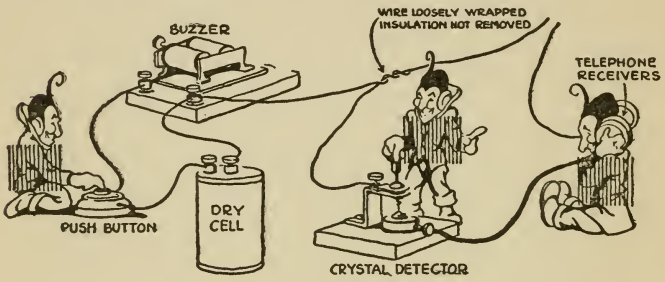
connection between the bottom plate of the condenser and the top of the inductance will have a negative charge due to the excess of the electrons there; and the bottom of the coil will be at ground potential or electric pressure. So the electrons will proceed to even things up by going around a path which may be supplied between the two wires connecting the bottom and the top of the coil.

Crystal Detector Connection. Such a path is provided by connecting the crystal detector to the top of the coil. The steel wire may be connected to this point. The base of the crystal will then be connected on to the telephone head-set. The other side of the head-set will be connected back to the bottom of the coil or ground.

Now, when the electrons have piled up on the bottom of the condenser, they may also pass on through the fine wire to the crystal and on through the telephone receivers back to ground. But they cannot come back that way, as they would not be able to get through the crystal to the wire. As a result, on each electron surge, some of the electrons will pass through the crystal detector to the telephone receivers to ground. These rapid, hammer-like blows of the electrons on the telephone receiver coils will all be in one direction, and will therefore constitute a general electron movement in one direction through the receivers. The electron surges are on the average some eight hundred thousand times per second. The tone changes in their intensity will only average 800 times a second. In order to take up this thousand-to-one difference, a small fixed condenser is added across the telephone receivers. This smooths out the thousand-time faster pulses and allows an average number of electrons to pass steadily through the telephone receivers, until the intensity of the rapid surges changes at

the much slower rate corresponding to the tones transmitted. The fixed condenser should have a value of about .002 microfarads. A microfarad is a unit for measuring the capacity of a condenser.

Crystal Detector Test. It is very convenient to have a means of adjusting the crystal when it is not known whether there are any radio waves active or not. This is easily accomplished by



Buzzer Crystal Test

connecting up an ordinary buzzer. A buzzer is the vibrating part of a door-bell. To operate the buzzer it is only necessary to connect its binding posts to a dry cell and a push button. The dry battery and push button are connected together to complete the electric circuit. When the circuit is completed by pushing the button, the buzzer will buzz. It then acts as a small generator of ether waves. To make them quite strong in their effect on the crystal detector set-up it may be well to add an extra wire from one of the binding posts of

the buzzer. The insulation of this wire is taken off only at the buzzer connection. The other end is only wrapped loosely around one of the crystal detector wires.

While the buzzer is working, the steel wire is adjusted on the crystal until a point is found where the buzzing sound is heard nicely. It does not pay to keep hunting for the elusive ultra-sensitive point. Now, the buzzer is shut off, and a rustling sound should be heard in the receivers. On tuning the set, whatever signals are passing should be heard in good shape.

Care of the Crystal. Dust and grease from fingers are the two chief trouble-makers for crystal detectors. The crystal may be washed with soap and water and dried. Alcohol is excellent for both the washing and drying. The wire is best cleaned by cutting it off for a short distance. It may be scraped with a knife. The point does not want to be too sharp or it will "burn up" quickly.

Other Crystals. There are many types of crystals which may be used. Also other types of wire may be used. They all act on exactly the same principle, as a trap or a one-way valve for electrons.

Yet another type is the pressure contact on the crystal. The pressure should be fairly firm from the spring adjustment in these types. All of these crystal sets should be cleaned and cared for

in the same manner as the galena-steel wire combination.

Crystal detectors are certainly simple and effective without requiring batteries; so this device may well form the start for the radio-fan, which will lead him on from a sure foundation to the larger equipments.

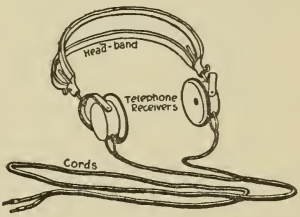
XIII

THE TELEPHONE HEAD-SET

"*Put armour on your ears.*"

—SHAKESPEARE.

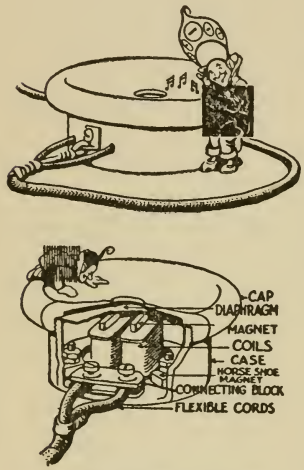
ALEXANDER GRAHAM BELL certainly made an epoch-making device in the telephone receiver such as goes with every telephone instrument. By adaptation, the same principles have given one of the most useful devices for radio work. The receivers are made in the form of what is known as "watch-case" receivers for radio work. Two of them placed on a band to fit the head make up the head-set.



Complete Head-Set

Permanent Magnet. If the cap of the telephone receiver is unscrewed, a thin piece of iron will be found which is held to the base by magnetism. The thin piece of iron may be slid off, using care not to bend it. The source of this magnetism will be found in the circular iron piece in the bottom of the receiver.

This piece of iron, which is not quite a complete circle, is a form of the old familiar red horseshoe magnet. The two ends of the magnet are the "Poles"; one of them is a north pole and the other is a south pole. These names are used as they indicate the direction in which the respective poles would be attracted if the magnet were free to swing as a magnetic compass. Any piece of iron which is brought near the poles of this magnet will be strongly attracted. For receiver work, however, it is necessary to produce variation in this pull, so that the thin piece of iron will be made to bend back and forth. To accomplish this, the two little spools of wire which take up so much room in the receiver are used.



The Telephone Receiver

Electro-Magnet. An electro-magnet is a coil of wire through which a current is passed. Usually the coil of wire is wound on a piece of soft iron. Whenever current passes through such a coil the combination of coil and iron becomes a magnet to draw pieces of iron to it. The fact that the

magnetic pull is there only when the current is on makes the device a very useful one for changing electric energy into mechanical motion. These coils are seen everywhere in electricity: door-bells, motors, telegraph sounders.

In the telephone receiver these electro-magnets are mounted one each on the ends of the permanent steel magnet poles. By this arrangement, the magnetism of the permanent magnet is carried up through the iron in the coils so that the thin sheet iron is attracted. Now, when small electric currents pass through the electro-magnets, the electro-magnetism will be added to or subtracted from the pull of the permanent magnet on the thin iron, depending upon the direction of the current through the electro-magnets. The small electric currents are able to change the pull of the permanent magnet on the thin iron much more easily and better than they could produce a pull of their own without the permanent magnet.

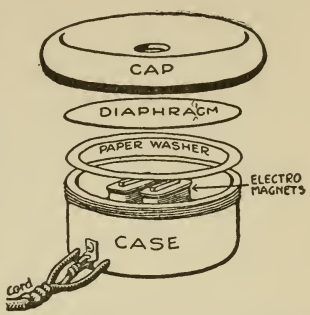
Diaphragm. Instead of saying "thin piece of iron" each time, it may be well to refer to the correct name of "diaphragm." This diaphragm of the telephone receiver has a large effect on the quality of the instrument. It should be quite thin and of the purest iron obtainable. Swedish iron still has a claim for being the best.

Action of the Receiver. The purpose of the telephone receiver is to transform current changes

into sound. The radio detector supplies the current changes in step with the sound at the transmitting station. The electro-magnet coils in the telephone receiver have these electric currents pass through them. As these currents pass, the magnetic effect changes. If the current happens to go in one direction through the coil, one end of that coil becomes a north magnetic pole and the other end a south magnetic pole. Now if the current is reversed, the magnetic poles will also be reversed. These magnetic poles are very weak, however, compared to the permanent magnetism of the steel horseshoe in the base. These little electro-magnets are on the pole pieces of the permanent magnet, so the effect of current passing through them will be to weaken or strengthen the magnetism of the horseshoe magnet, depending upon the direction of the current. As this magnetism changes, the pull on the thin iron diaphragm changes. As the diaphragm wiggles in and out, it pushes the air in and out, and this makes sound.

Diaphragm Clearance. It is evident that if the diaphragm is to give out sound, it must be able to vibrate freely. The trouble with many receivers is that the diaphragm has not got sufficient clearance from the pole pieces of the electro-magnets. This can be very easily found out. If the diaphragm is tapped in the assembled receiver, it should give out a hollow sound. If it

strikes dead against the pole pieces, it is seen that there is not sufficient clearance. This can usually be remedied by tightening the cap of the receiver a little. If this does not accomplish it, the cap may be removed and the diaphragm reversed, and then the receiver reassembled.



Paper Washer to keep Diaphragm from Striking Electromagnets

Paper Washer. If the diaphragm still does not clear the pole pieces, a paper washer may help. Cut out a washer from ordinary white paper, the diameter of the diaphragm. Cut out the inside of this paper to within an eighth of an inch of the edge. This washer is then inserted between the base of the receiver and the diaphragm.

The diaphragm should never be bent. If it is, about the only remedy is to get a new one.

Receiver Resistance. Each receiver will have a total resistance of one thousand to eleven hundred ohms. (An ohm is the unit of resistance.) So the two receivers in series will have a combined resistance through which the current must pass of 2,000 to 2,200 ohms.

In order to get the weak electric currents which the radio detector delivers to make an appreciable

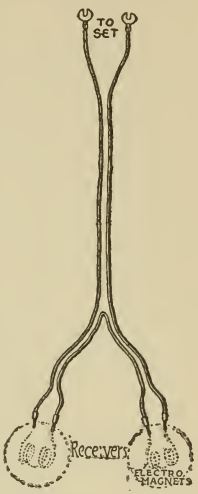
effect it is necessary to have a large number of turns of wire around each of the electro-magnets in the receiver. The turns are of a very fine insulated copper wire. This means that the wire necessarily will have quite a resistance. Resistance is therefore a certain measure of the number of turns in the coils. It would be possible to use resistance wire in a receiver and get a high resistance with a very few turns, and produce a very poor receiver. So resistance is one of the necessary inconveniences of having a large number of turns rather than any advantage in the design of the receiver.

It does not pay to go much above 2,200 ohms in a pair of telephone receivers. It is far better to spend the extra value in getting the very best mechanical design.

As the wire used in receivers is very fine, great care must be exercised when the receiver is open not to touch and break these fine wires where they connect to the binding posts inside the receiver.

Head-Set Connections. Flexible cords are supplied with head-sets. These consist of two conductors of insulated braided wire. Metal terminals are provided for making connections. The two receivers must be connected in series. This means that one of the connections from the terminals is carried down into one receiver. There is then a short "V" connection running from this

first receiver to the second, and then the second receiver carries the current on to the second cord terminal. The same electric current, which means the electrons, of course, must pass in succession through this whole series. If there is a break anywhere in this circuit, nothing will work.



Telephone Cords

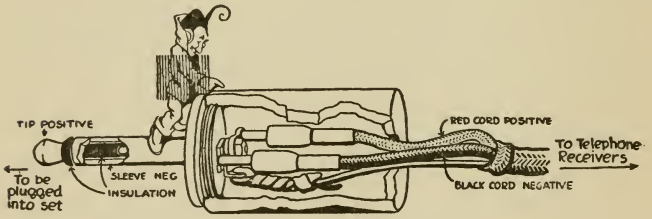
The terminal connection should be soldered to the fine braided wire of the cords. The straight terminals are called "tips," and the ones shaped like eyelets are called "contuse" terminals.

Cord Breaks. With excessive wear, the cords break inside. This usually first shows up by the receiver going in and out of service as the cord is moved. This means that the fine tinsel-like wire which makes up the cord is broken.

The position of the break may be determined by putting the head-set on and going along the cord, pushing it up together along its length. A point will be found where the connection may be made and broken. This is the break. Usually it will be near one of the ends. If this is the case, it is better to cut off the cord at this point and resolder the terminals to the shortened good portion.

If the break is farther along, the cord may be opened and the broken ends fastened together by wrapping them with some fine bare copper wire, say No. 34. If the wrapping is well done, it will not be necessary to solder the joint, which is a very difficult thing to do with such fine wire. The joint should of course be reinsulated by wrapping with coarse thread. This is called "serving." To serve a joint, a loop of the thread is taken back along the joint to be served and then the thread is wound back around this loop, covering the loop and the joint. When the wrapping is complete over the joint, this loop end furnishes something to tie the final end to.

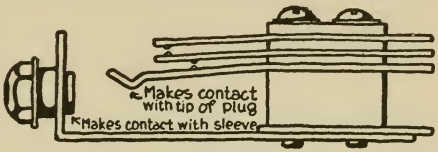
Plug Terminal. Plugs are provided for amplifier



Telephone Plug

sets to furnish a ready means of connecting in head-sets. These plugs have an inside brass rod coming out to the end of the plug as the "tip." One of the cord terminals is fastened to this tip in the holder of the plug. Around the tip rod there is some rubber or other insulation, and then

around this there is some brass tubing which makes the "sleeve" as the other contact. This sleeve is connected to the other terminal of the head-set cord, in the holder of the plug. The plug is inserted in a "jack," in the set, which has two spring contacts, one of which makes contact with the tip of the plug and the other with the sleeve.



Jack in Amplifier

Demagnetized Receivers. If electric currents go through telephone receivers always in such a direction that the electro-magnets produce magnetism in opposition to that of the permanent magnet, the receivers will be gradually made weaker as the permanent magnet will lose its magnetism or become "demagnetized." If a pair of telephone receivers happens to get across alternating current power, this demagnetizing will happen immediately. So care must be used in seeing that only the proper currents get in the telephone receivers.

Tube sets furnish a large amount of direct current into the telephone receivers, and if this current is always in the demagnetizing direction, the receivers will gradually lose their "permanent" magnetization. To avoid this, the current should be in such a direction that it strengthens the

permanent magnet. This can be readily determined by holding the finger on the diaphragm lightly when connecting the receivers to the amplifier. If the diaphragm goes in further, it is evident that the magnetism is increased, which is as it should be.

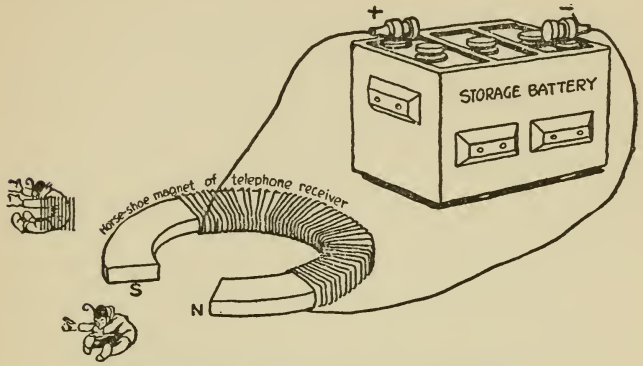
Red Cord. The manufacturers are standardizing head-sets by supplying the receiver cords with a red thread running through one of the wire's insulation. If this wire is connected to the positive terminal of the amplifier set, the current will be in the corresponding direction to increase the magnetism.

Further standardization has this red cord go to the tip of the plug, and the jack inside the set is so connected that the spring contact which connects with the tip of the plug is positive.

Remagnetizing Receivers. If the receivers become demagnetized, it is possible to remagnetize the permanent magnet. This is best done in a shop which specializes in this work. But if there is none available, this remagnetizing may be done at home.

The receiver must be taken apart. This must be done very carefully to avoid breaking the fine wires with which the electro-magnets are wound. The part to be remagnetized is the horseshoe magnet. This is taken out of the case and wound with some fifty turns of insulated wire of say size

No. 23. These turns are taken around the piece of metal in one continuous direction. The ends of the fifty turns are then connected for a short time only to a six-volt storage battery or three dry cells. On trying out the holding power of this horseshoe magnet for pieces of iron it should now be found to be quite strong.



Remagnetizing Receiver Permanent Magnet

The receiver is then re-assembled, and the red thread cord is connected to the terminal, which it is found by trial will when connected to the plus plate of a battery cause the diaphragm to be pulled in farther by the combined permanent magnetism and the electro-magnetism.

With a little care in their treatment, telephone receivers for head-sets will give very excellent continuous service for years. They are the most reliable part of the set when carefully used.

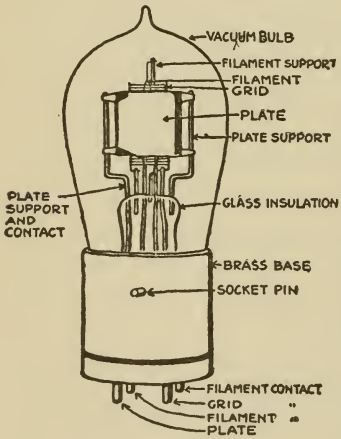
XIV

AMPLIFIERS

"A lover's ear will hear the lowest sound."

—SHAKESPEARE.

A NEW electric light is on the market, but the light that it gives is nothing compared to its wonderful powers of amplifying signals, particularly for radio work. It is called the vacuum tube.



The Vacuum Tube

Edison noticed in some of his first research work in the electric light that if he put a small metal plate inside the glass bulb that a current would flow between the lighted filament and this metal plate. Everyone has noticed that the inside of the glass of an old electric light has become blackened. As

might well be supposed, this is caused by the disintegration of the filament.

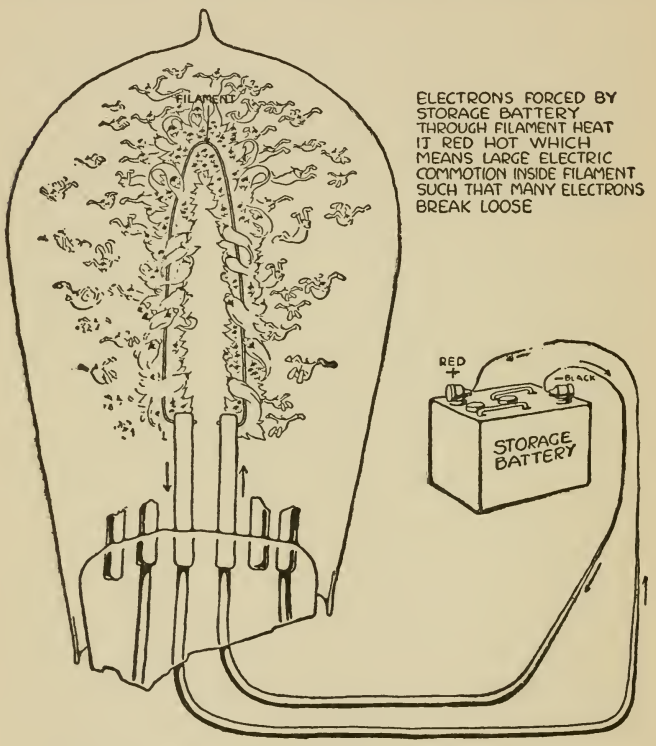
When the filament is heated, it is naturally in a more sensitive mechanical condition than when cool. This condition means that it will gradually disintegrate; but most interesting of all is the fact that this process frees the little electrons.

Vacuum. The vacuum tube has a filament as an ordinary electric light. To prevent this filament burning away immediately when it is heated by the passage of electric current through it, the space inside the bulb is pumped as empty of air as possible. The better it is pumped out, the "harder" the tube is said to be. With all the air pumped out, there is naturally nothing left but the vacuum—that is nothing except ether.

Free Electrons. The filament is usually made of tungsten, but, as everything else, this is largely made up of electrons.

Heating the filament by an electric current means of course that electrons are being forced through that filament by a source of electric energy, such as the storage battery. Now, inside the wire filament, the electrons move around very fast, but they are always bumping up against particles of the matter in the wire. If there is a large electric driving force urging on this bumping group of electrons, the drift of the movement will heat the wire red hot.

When it is heated red hot, the particles of the wire are in violent agitation (speaking in terms of electrons) and the result is that many of the


FILAMENT
ELECTRONS FORCED BY STORAGE BATTERY THROUGH FILAMENT HEAT IT RED HOT WHICH MEANS LARGE ELECTRIC COMMOTION INSIDE FILAMENT SUCH THAT MANY ELECTRONS BREAK LOOSE
RED +
BLACK −
STORAGE BATTERY

The Heated Filament

electrons will jump right out of the wire into the empty space around the wire. It is an action similar to that of the formation of steam over

boiling water. So the first principle of the vacuum tube is the opportunity for forming free electrons floating in space around the heated filament.

The Plate. The most obvious part of the vacuum tube is the metal part which is in the form of a flat cylinder around the filament. This is called the plate of the tube.

The electrons floating around the filament are of course negative. So if the plate is made positive, the electrons in the tube will jump to the plate at once. There is nothing in their way, either, so they will move very quickly.

To start this action the plate is made positive by pulling out some of the electrons already in the plate. To do this, it is only necessary to connect the plus pole of a dry battery to the wire which runs up through the base of the tube out through the glass stem and acts as a support for the plate. The dry battery acts as a pump for moving electrons; so if its positive pole is connected to the plate to pull out the electrons, the circuit must be made complete to give back to the filament its deficiency of electrons. This is done by connecting the negative of the dry battery to the filament. The complete circuit of the dry battery then consists of pulling electrons out of the plate, forcing them through the battery, pushing them out through the black wire into the filament, and the electrons freed by the heated filament "close the

circuit" by passing from the filament to the plate across space inside the tube.

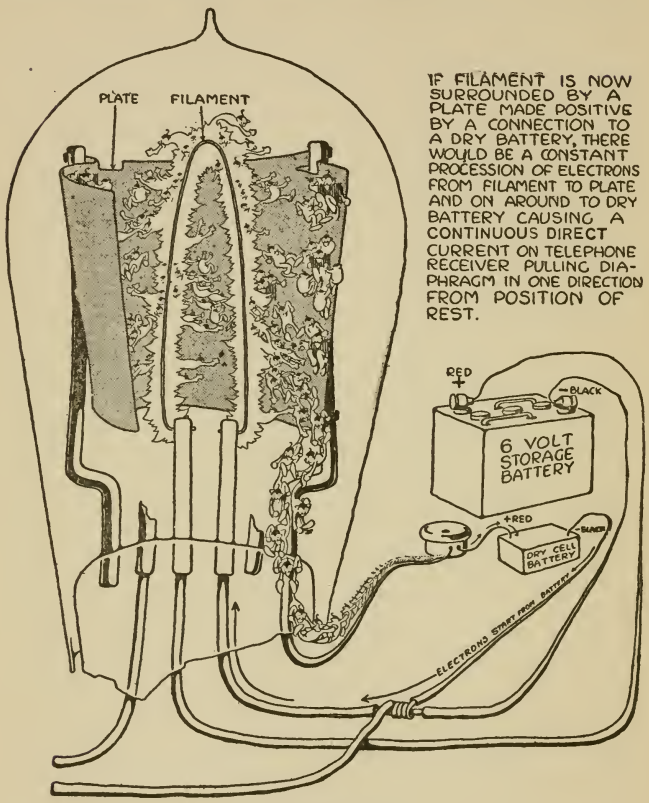


PLATE
FILAMENT
IF FILAMENT IS NOW SURROUNDED BY A PLATE MADE POSITIVE BY A CONNECTION TO A DRY BATTERY, THERE WOULD BE A CONSTANT PROCESSION OF ELECTRONS FROM FILAMENT TO PLATE AND ON AROUND TO DRY BATTERY CAUSING A CONTINUOUS DIRECT CURRENT ON TELEPHONE RECEIVER PULLING DIAPHRAGM IN ONE DIRECTION FROM POSITION OF REST.
RED +
-BLACK
6 VOLT STORAGE BATTERY
+RED
-BLACK
DRY CELL BATTERY
ELECTRONS START FROM BATTERY

The Plate Action

Vacuum Tube Batteries. From the two forces required to operate vacuum tubes it is evident

that two separate batteries are required. The two requirements are, first, a battery to heat the filament; second, a battery to pull the electrons across the vacuum and send them back around to the filament.

The first battery is called the "A" battery and must be able to supply a good current at a low pressure or voltage. Electric current is measured in "amperes," and the electric pressure is measured in "volts." Most of the filaments in vacuum tubes take about one ampere of current to light them correctly. The pressure required to send one ampere of electrons pushing through the resistance in the filament to heat it is about six volts.

New vacuum tubes are now coming out on the market which require only a dry cell to light the filament. They are naturally a little more delicate to handle and to use.

For the plate battery force, known as the "B" battery, more pressure is required. The electric force of attraction of the positive plate on the negative electrons must be exerted over a distance of about a quarter of an inch. While the electrons will move very fast once they get started across this space, it takes considerable electric pressure or voltage to be felt at these distances on the free electrons. A pressure of from twenty to eighty volts is usually necessary on this. But the

actual number of electrons that come across is relatively quite small, so that only a small current value is necessary. Such qualifications of high-voltage and low-current amperage are readily available in dry cells. These are usually made up into groups of fifteen cells connected together to make one battery of twenty-two and one-half volts. A red wire from this "plate" battery indicates the positive terminal of the battery. A black wire indicates the negative terminal.

A vacuum tube with the filament connected to a six-volt storage battery will let through a flow of electrons across the vacuum to give a current of about two-thousandths of an ampere, or two "milliamperes" if the voltage pressure is about 40 volts. For 40 to 45 volts, two of the fifteen-cell dry batteries are used in series, i.e., the red wire on the first is connected to the black wire of the second. This leaves the black wire of the first to be connected to the filament and the red of the second to be connected to the plate. If a telephone head-set is now included in series between the plate battery and the plate of the tube, this current will pass through the telephone receivers. Any change in this current will then be noted in the receivers. It is now understood why such fine wire and so many turns are required in the head-sets to note such small values of current.

The Grid. These little electrons floating across

space between the filament and the plate of the vacuum tube are in a very sensitive condition.

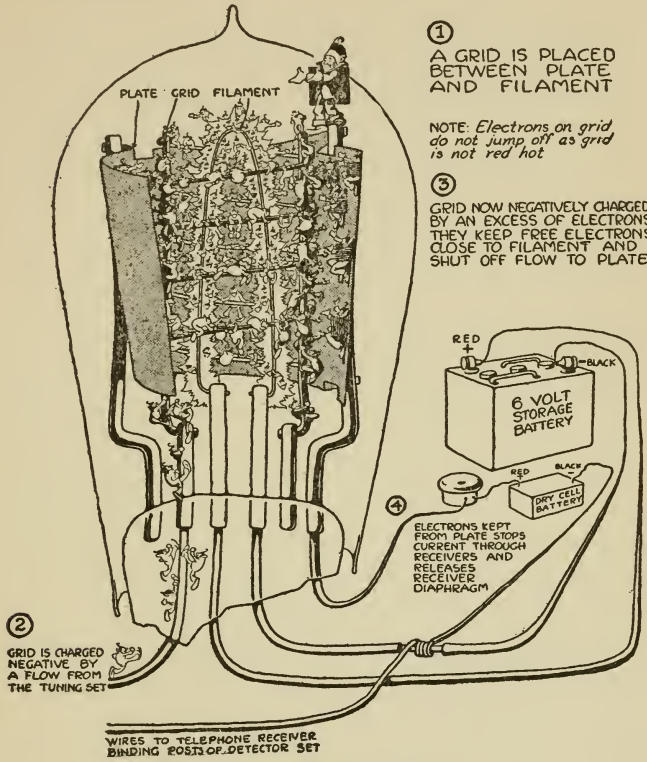


PLATE GRID FILAMENT
1
A GRID IS PLACED BETWEEN PLATE AND FILAMENT
NOTE: Electrons on grid do not jump off as grid is not red hot
3
GRID NOW NEGATIVELY CHARGED BY AN EXCESS OF ELECTRONS. THEY KEEP FREE ELECTRONS CLOSE TO FILAMENT AND SHUT OFF FLOW TO PLATE
RED +
BLACK -
6 VOLT STORAGE BATTERY
RED
BLACK
DRY CELL BATTERY
4
ELECTRONS KEPT FROM PLATE STOPS CURRENT THROUGH RECEIVERS AND RELEASES RECEIVER DIAPHRAGM
2
GRID IS CHARGED NEGATIVE BY A FLOW FROM THE TUNING SET
WIRES TO TELEPHONE RECEIVER BINDING POSTS OF DETECTOR SET

With a Negative Grid

They are not tied within the confines of a wire, but just speed across to the plate by the positive attraction this plate has for them. Now, to

bring the vacuum tube to its full efficiency to which it has come in radio work, a grid has been added. This grid consists of a short coil of wire in the form of a grid which is placed between the filament and the plate, and is in consequence directly in the path of the electrons moving from the filament to the plate. Fleming invented the vacuum tube for its application to radio work, and De Forest added this grid to improve its effectiveness greatly.

Electric Charge on the Grid. This grid interposed between the filament and the plate is in a very important place with respect to the electrons passing through the vacuum. Any electric charge on this grid will have a very great effect on these electrons.

For amplifier work, this charge on the grid may be obtained from the detector. If it is a crystal detector, it is only necessary to take the two terminals which would ordinarily go direct to the telephone receivers and place one of them in direct connection to the grid of the tube to be used as an amplifier. The other connection from the crystal detector set is connected to the filament. The head-set is of course disconnected from these two points and put in the plate circuit of the vacuum tube where the signals will be amplified.

Suppose the radio signals which are coming in are such as to be rectified by the crystal to give a

negative charge to the wire connected to the grid. This means that the other connection will give a positive charge to the filament. In electric work, the plus and the minus always take place together. That is if negative electrons are taken from one place, making it thereby positively charged, an equal number of electrons will be sent somewhere else to give this other place a negative charge. It may be said that electrons cannot be destroyed (fortunately for them). They can only be moved. Where they come from becomes positive with respect to the place they go to.

So in this case, it is assumed that electrons are sent by the detector to the grid. The other connection from the detector set will endeavour to even up this loss of electrons by pulling some out of the filament to which it is connected and thereby making the filament positive.

Now, if the grid has more than enough electrons on it, it will have a very big effect on the electrons trying to get from the filament to the plate. The grid is much nearer the filament than the plate is, so this negative charge on the grid will hold back the electrons from the filament greatly. One volt of electric pressure on the grid may have as much effect as ten volts change in the voltage on the plate. Such a tube would be said to have an amplification factor of ten. In other words, one electron on the grid will have the strength of ten

in the plate circuit. The audio signals to be amplified are brought on to the grid, and the effect

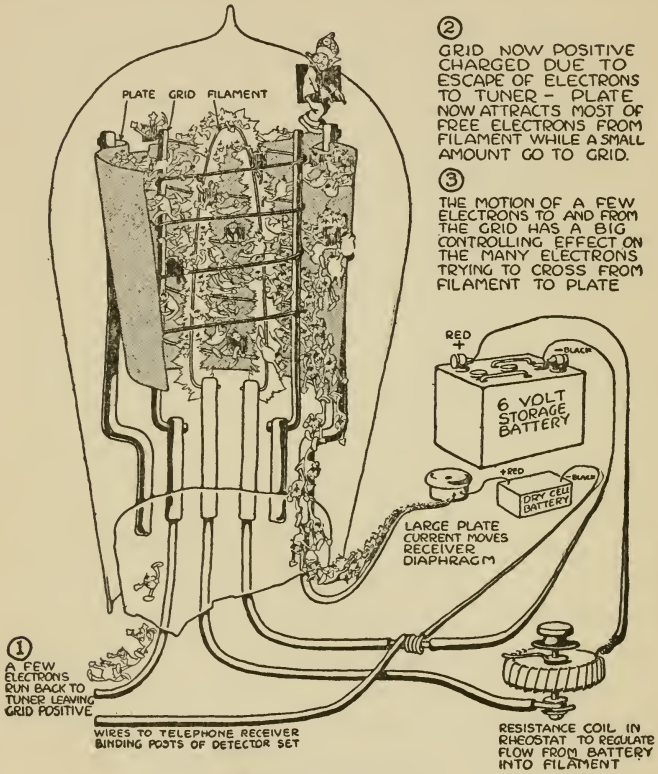


PLATE GRID FILAMENT
2
GRID NOW POSITIVE CHARGED DUE TO ESCAPE OF ELECTRONS TO TUNER - PLATE NOW ATTRACTS MOST OF FREE ELECTRONS FROM FILAMENT WHILE A SMALL AMOUNT GO TO GRID.
3
THE MOTION OF A FEW ELECTRONS TO AND FROM THE GRID HAS A BIG CONTROLLING EFFECT ON THE MANY ELECTRONS TRYING TO CROSS FROM FILAMENT TO PLATE
RED +
+BLACK
6 VOLT STORAGE BATTERY
+RED
-BLACK
DRY CELL BATTERY
LARGE PLATE CURRENT MOVES RECEIVER DIAPHRAGM
1
A FEW ELECTRONS RUN BACK TO TUNER LEAVING GRID POSITIVE
WIRES TO TELEPHONE RECEIVER BINDING POSTS OF DETECTOR SET
RESISTANCE COIL IN RHEOSTAT TO REGULATE FLOW FROM BATTERY INTO FILAMENT

With a Positive Grid

is observed in the telephone receivers in the plate circuit. A small amount of energy in the grid circuit will have a big effect in changing the

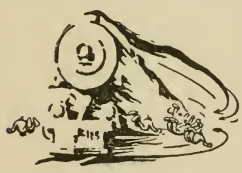
energy in the plate circuit. A signal which can only just be heard with the crystal detector alone and the telephone receivers, will be brought up to good value with one vacuum tube amplifier.

It is possible to carry this effect farther and have two or even three vacuum tubes which will take the weaker signals which can be just heard in the telephone head-set and bring them through the successive stages of amplification to such a value that they will even work a loud speaker. To carry these signals on through two or more vacuum tubes, a new device is necessary. This is the transformer.

Transformers. Electric power is represented by the current flow with the voltage pressure behind it. In fact, electric energy is measured directly as the product of the pressure and the current, or as volts times the amperes. One volt times one ampere is one watt of power. Sometimes the particular resistance which has to be worked through requires a high-voltage pressure and only a small current. This, for example, is just the case when acting on the grid of a vacuum tube. Whatever energy is available to drive on to the grid would be most effective at a high voltage and a correspondingly low current. It takes relatively few electrons on the grid to give it a negative charge, but it takes considerable voltage pressure to drive them there. The grid and the filament of

the tube may be considered as the two sides of a condenser, but the capacity of this condenser is very small due to the size of the parts. It therefore takes considerable pressure to get even a few electrons on it. The energy available to work the grid may be in the form of a low voltage and a relatively greater current. A device is necessary to transform the energy from low voltage—high current to high voltage—low current. The transformer does this.

It has already been pointed out that when electrons start to move around the turns of a coil, there is a kick back of the electrons in other turns. This fact is made use of in the transformer. The transformer consists of two separate coils. One is called the primary coil, as it takes the electric current which is to be transformed. The other coil is called the secondary, because in it are formed the currents which are to be of the different type. The principle is very simple. If it is desired to "step up" the voltage, as it is described, and the consequent reduction in the current is not serious, all that it is necessary to do is to have an iron core and wind many more turns on the secondary coil than are put on the primary. If this is done, when the electrons start around the primary turns,



Back Surge Caused by Onrushing Current

they will produce a kick back in the many more turns of the secondary. As the secondary turns all push together in one direction, the voltage of the secondary will be much greater. As there is much more wire for the currents to go through in the secondary, the current will be much less, however. Transformers are fairly efficient, so that the power of volts times amperes in the secondary will be about ninety per cent. as large as the volt-amperes put in the primary, and the desired step up in voltage is obtained.

To use such a transformer with vacuum tubes, the primary is put in place of the telephone receivers, in the plate circuit of the first vacuum tube. Whatever current changes are then produced in this plate circuit by the detector acting on the grid of the first tube will be carried into this primary. The voltage pressure of these changes will be stepped up in the secondary of the transformer. The secondary is connected between the filament and the grid of a second tube. This will change the electric charge on the grid of the second tube to correspond to the signals received. In the plate circuit of the second tube will be put the telephone head-set receivers. The signals will be greatly amplified by this process.

Amplification may be carried one step farther with another transformer connected similarly to a third vacuum tube. The output of this should

work a loud speaker without any difficulty if the signals can be heard at all from the original crystal detector.

Statements have frequently been made that a vacuum tube may not be used to amplify crystal detector signals. Where this superstition originated is unknown. The process can be carried out very nicely as just described.

These transformers are called audio transformers as they handle the audio currents which would operate telephone head-sets to produce sound. As a matter of fact, the primary and secondary windings on these transformers are made of rather fine wire, so that a large number of turns may be placed on the primary, to take full advantage of the rather weak signals, and then a much greater number is necessary to step this up in the secondary. As No. 40 insulated wire is used for this work, it is realized that only machinery is able to handle such fine wire.

Amplifier Quality. One of the most serious studies in amplifier design is to produce the amplification without distorting the quality of the amplified signals. Distortion is produced by an outfit which amplifies one tone more than it does others. Music is made by the proper mixture of a large number of tones. If some of these are unduly amplified, the quality is destroyed. In order to amplify all pitches of tones equally, research

work has been carried out to give to the amplifier transformers what is called a "flat characteristic" which means that they amplify all tones in the scale equally.

Neither the tubes nor the transformers can be pushed to the limit of amplification without getting this distortion.

Tube Noises. Two hindrances keep it from being possible to continue this process of amplifying indefinitely. The chief one is tube noises. The tube filament in disintegrating makes little explosions inside the tube as the particles break away from the filament. Although these are very small, when many amplifier stages are used in succession these noises are amplified themselves, as well as the desired signals. Three stages of audio amplification is usually all that is possible.

Howling. The second hindrance to amplification is "howling." The receivers make a terrible howling noise at times. This is due to a fault in the wiring. If there is any opportunity for the amplified currents to get back into the grid of a tube, this tendency to howl shows itself. The output of any tube has say five times the voltage of the input. Suppose a current is increasing in the grid, and by poor wiring it is possible for some of the increasing output of the plate of a tube to get back on to the grid. This will make the increase even more. Quickly this increase will

carry the tube to its full limit of output. The tube will then return to normal, and the kick-back action will start again. This will keep up steadily and show itself as a horrible noise coming out of the telephones.

The way to prevent this is to keep the wiring from the input and the output of every tube and transformer as well separated as possible. If the wiring is all bunched together, there is bound to be this tendency to howl if the tubes are working. Such action is also termed "feed-back," although there is a much more legitimate form of this feed-back action which will be described later.

Coated Filaments. Most vacuum tubes are of tungsten wire filaments. These light quite brightly when working. As the whole purpose of the filament is to give off electrons, it is easily appreciated that there might be some substances which would give off these electrons more easily. There are such in the form of coatings of oxides of some of the metals. These oxides are coated on to a fine platinum filament. It is only necessary to heat such coated filaments to a dull red heat to get off a good supply of electrons.

The answer on the heating of any filament tube is to keep it as low a temperature as possible which will still give signals. This will prolong the life of the tube considerably.

Mastery of the vacuum tube is one of the high-

est achievements of the radio-fan. The vacuum tube is a distinct contribution of the science of radio, and its action is one of the nicest expositions of the electron action that there is; in addition, the vacuum tube has come into other uses now, such as for a loud-speaker work for conventions. Also the vacuum tube is what made transcontinental wire telephony feasible. At various points across the continent these little tubes pick up the weak voice currents, and as "repeaters" speed them on their way with much increased intensity.

XV

GAS TUBE DETECTORS

"Observe always that everything is the result of a change."
—Marcus Aurelius.

Little electrons floating in space have yet other uses in radio. They have made very efficient detectors to rectify the very rapid swingings in the receiving antenna to render them into audible sounds. It will be remembered that the aerial picks up the music of the ether waves in the form of rapid electron surges back and forth in the tuned electric circuits. These are so rapid that they must be averaged in order to get some meaning out of the changes in intensity of their swings. The crystal detector did this by being a valve to let electrons through in one direction only. The gas-filled tube is another method.

Gas-Filled Tube. In place of having a complete vacuum in a tube for detector purposes, exactly the same construction as before is used, but a small quantity of gas is let into the tube after it has been pumped empty of air. This small quantity of gas acts very queerly inside the tube. The finest

particle of a gas which can still be identified as gas is the "molecule." This molecule is made up of a group of the friendly electrons all running around what is called the positive nucleus of the molecule. In other words, this molecule of gas consists of a positive nucleus trying to hold in check a group of very active electrons. The very activity of these electrons is what makes it a gas.

This small quantity of gas inside the tube has quite an effect on the movement of the electrons inside the tube. Free electrons are formed around the heated filament as before. With the plate of the tube positive, some of these electrons will start at full speed for the plate; but they will bump into some of these gas groups. If they hit them hard enough, they will knock them all to pieces and the result will be many more electrons free in the tube, as well as a positive nucleus which will go floating over to the filament, surrounded by the negative electrons. Here the positive nucleus will gather some more of the electrons around it to get back to its original state as a particle of gas. All of this action means that more electrons will get free from the heated filament and get over to the plate.

This breaking up of the gas molecules happens at a more or less critical velocity of the electrons running over to the plate. The velocity of these electrons is determined by the voltage on the plate which attracts them. So by appropriate adjust-

ment of the plate voltage, the gas tube will pass quite a good plate current. This critical value is around eighteen volts on the plate. If the plate voltage is increased slightly above this point there will be no corresponding increase in the plate current, and in fact there may even be a decrease. For detector action, the plate voltage is adjusted to this value, just above the critical point.

Now, if the grid is made slightly negative by some electrons pushed on to it from a radio tuner, the plate current will increase as the electrons flowing across the tube space will be slowed down a bit to the critical value where the breaking-up process takes place. Likewise, if the grid is made positive, the space electrons will be speeded up. In both cases, this means more plate current. When the velocity was decreased it was just right to break up the gas molecules and get more electrons, and when the electrons were speeded up, naturally more of them got across. So that at this point, no matter whether the grid is made positive or negative, the plate current will go up with changes on the grid. The telephone receivers in the plate circuit of such a tube would therefore show this increase as sound directly.

Gas Tube Connection. It is only necessary to connect the grid and filament respectively to two points of the radio tuner which have electron pressures developed between them on the passage

of the ether waves. Two convenient points for this are the two sides of the tuner coil. Now, whenever radio waves pass, the grid potential of the gas tube will be changed, and the plate currents of the tube will be increased. If the intensity of the radio waves is great, the plate current will be large. If the intensity is low, the plate current will be back near its normal value. In consequence, the plate current will follow the ether wave intensity changes directly, and thereby reproduce the sound which controls these ether waves when they start from the transmitting station.

Gas Tube Plate Batteries. Plate batteries are supplied particularly for gas tubes, which have several taps at the positive end. These taps make it possible to adjust the plate voltage to the best point for getting this detector action.

Many plate batteries have only one such extra connecting plus lead, which is the short red one. This is just about the right value for the gas tubes.

Potentiometers. For gas tube adjustment, it is usually well to have some more accurate control of this voltage. This is accomplished by the aid of a potentiometer. This device is made of a coil of bare resistance wire on which a slider will run to pick up the best point in adjustment. This wire resistance is rather high, in the neighbourhood of 200 ohms. This resistance is put directly across the filament battery. The amount of

current which it uses up is insignificant, due to the high resistance. If the black negative lead of the plate battery is connected to the sliding contact on this resistance, the fine adjustment may be realized.

It is usual to consider the negative terminal of the filament battery as at zero voltage. This is absolutely so if this point is connected to ground, as is frequently done. All voltages in electricity are relative, so this is a perfectly legitimate thing to do. The other end of the plate battery will then be plus six volts above this value. Other points along the filament battery would be between this value of plus six volts and zero. The slider, as it is moved between its extreme positions, will cover all these values from zero to plus six volts also. It certainly will be at zero when the slider is at the end directly connected to the negative terminal of the filament battery, and it will be at six volts when moved to the end connected to the plus six volt end of the filament battery. It changes smoothly between these values as the slider moves. So if the negative plate terminal is connected to this slider, the plate voltage will be moved up and down by this six volt difference, on top of its own value. This smooth adjustment makes it possible to find just the right spot to get maximum signals.

Rheostats. It is necessary to have means for controlling the filament heating current carefully.

This is done with rheostats. A rheostat is another slide wire resistance, but of much larger wire than the potentiometer. A resistance of three ohms is usually sufficient for these rheostats. The wire of the resistance should be of such size as to carry the necessary current. For one tube this will usually be one ampere. If the same rheostat is used for two tubes, it must be able to carry two amperes; for three tubes three amperes. It is not wise to have one rheostat control more than three tubes. The slider on these rheostats should make a firm contact with the wire. It should touch the wire in more than one place. Otherwise, the contact point will heat up and cause noise in the telephones. Poor contacts somewhere are a frequent cause of noise in receiving sets.

XVI

GRID LEAK–CONDENSER DETECTOR

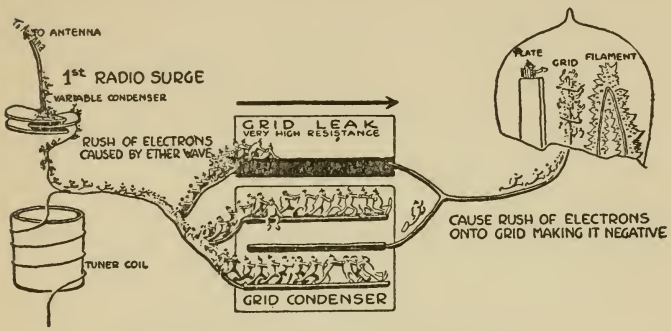
"The soft droppes of rain pierce the hard marble; many strokes overthrow the tallest oaks."

JOHN LYLY.

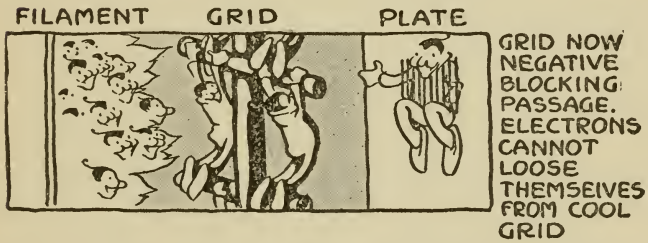
YET another and very popular form of detector is the grid leak-condenser which added to a "hard" vacuum tube makes a reliable detector. The hard or ordinary amplifier tube is connected as just described for the gas tube across the tuning coil of a radio set. This supplies the grid with the rapid surges of the electron changes. But the grid leak-condenser combination is added between the tuner and the grid of the tube. The condenser has a value of about .0005 microfarads capacity, and it is put directly in the lead between the tuner and the grid.

Now suppose electrons surge from the tuner into one side of this condenser. The electrons which were on the grid side of this condenser will then rush out on to the grid of the tube, and cut down the plate current. But this will be so quick as to produce no effect in the telephones. On the back

surge, however, something else will happen. The electrons will then rush out of the tuner side of the small grid condenser to such an extent as to pull some electrons away from the grid of the tube, and thereby make it positive. This will mean that



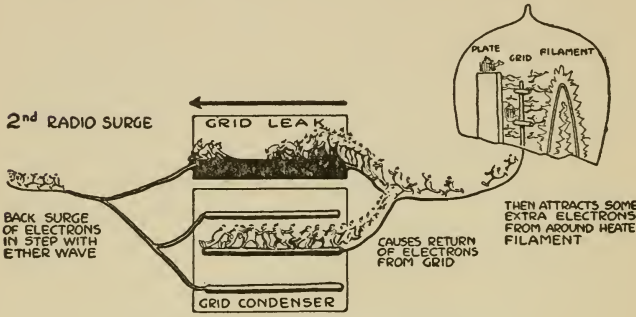
Radio Surge Acts Through Grid Condenser



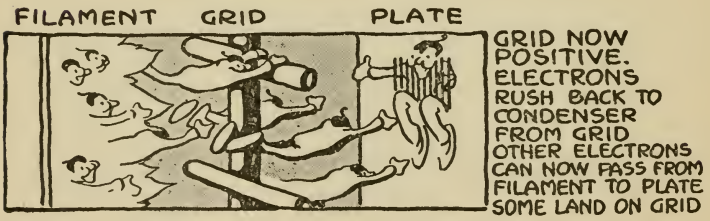
some of the free electrons in the tube will be drawn to the grid of the tube and out on to the wire connecting the grid to the small condenser.

On the next return surge of the electrons on the tuner side of the small condenser from the tuner, these extra electrons which came from the tube are

no longer free, but are trapped between the condenser and the grid of the tube. They cannot get out of the grid back into the vacuum of the tube, because the grid is not heated as the filament is. So they are trapped between the grid and the small

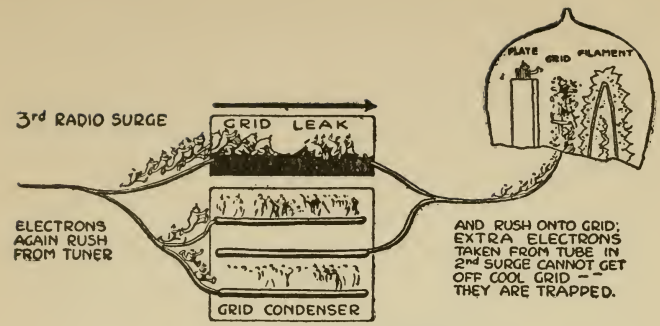


Trapping of Electrons by Grid

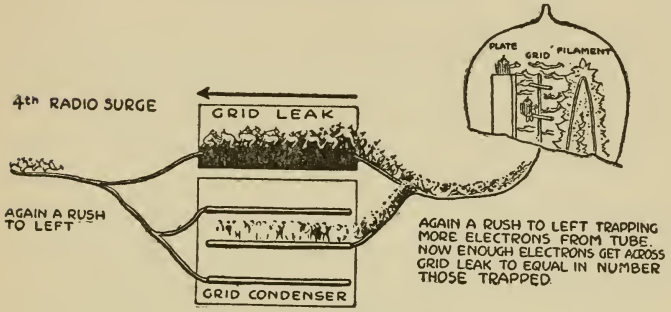

FILAMENT
GRID
PLATE
GRID NOW POSITIVE. ELECTRONS RUSH BACK TO CONDENSER FROM GRID
OTHER ELECTRONS CAN NOW PASS FROM FILAMENT TO PLATE
SOME LAND ON GRID

condenser. The result is that the grid is more negative than it was before, because of the excess of electrons it has now. The plate current in the tube will therefore go to a lower value than it did before.

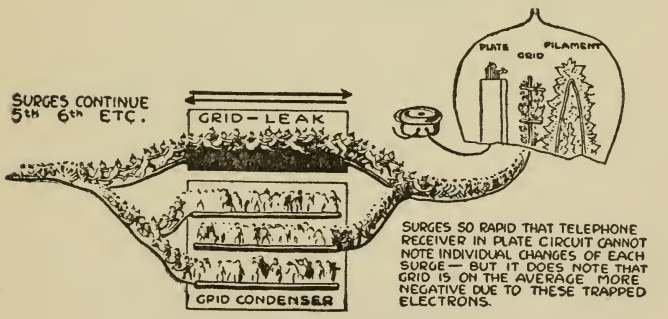
This trapping of the electrons will continue on


3rd RADIO SURGE
GRID LEAK
PLATE
GRID
FILAMENT
ELECTRONS AGAIN RUSH FROM TUNER
AND RUSH ONTO GRID; EXTRA ELECTRONS TAKEN FROM TUBE IN 2nd SURGE CANNOT GET OFF COOL GRID -- THEY ARE TRAPPED.
GRID CONDENSER

Grid Increasingly Negative


4th RADIO SURGE
GRID LEAK
PLATE
GRID
FILAMENT
AGAIN A RUSH TO LEFT
AGAIN A RUSH TO LEFT TRAPPING MORE ELECTRONS FROM TUBE. NOW ENOUGH ELECTRONS GET ACROSS GRID LEAK TO EQUAL IN NUMBER THOSE TRAPPED
GRID CONDENSER

More Electrons Trapped


SURGES CONTINUE 5th 6th ETC.
GRID-LEAK
PLATE
GRID
FILAMENT
SURGES SO RAPID THAT TELEPHONE RECEIVER IN PLATE CIRCUIT CANNOT NOTE INDIVIDUAL CHANGES OF EACH SURGE — BUT IT DOES NOTE THAT GRID IS ON THE AVERAGE MORE NEGATIVE DUE TO THESE TRAPPED ELECTRONS.
GRID CONDENSER

Decrease in Plate Current Caused

each positive swing of the grid, so that the grid will soon reach an average negative value below where it started, by the number of electrons which

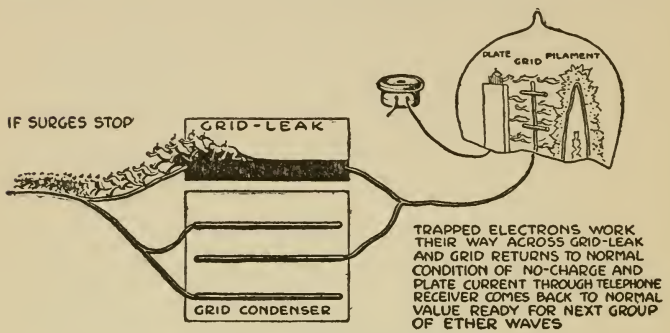


PLATE
GRID
FILAMENT
IF SURGES STOP
GRID-LEAK
GRID CONDENSER
TRAPPED ELECTRONS WORK THEIR WAY ACROSS GRID-LEAK AND GRID RETURNS TO NORMAL CONDITION OF NO-CHARGE AND PLATE CURRENT THROUGH TELEPHONE RECEIVER COMES BACK TO NORMAL VALUE READY FOR NEXT GROUP OF ETHER WAVES

Back to Normal Condition

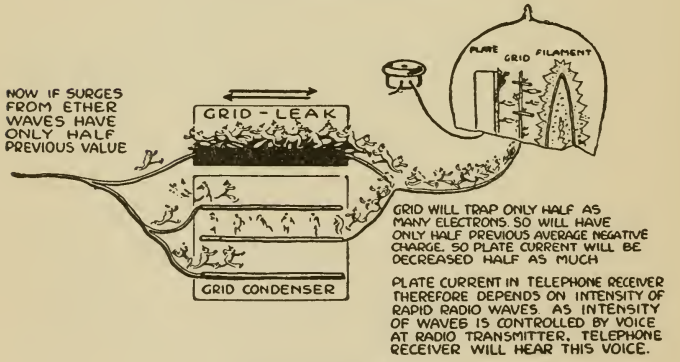


PLATE
GRID
FILAMENT
NOW IF SURGES FROM ETHER WAVES HAVE ONLY HALF PREVIOUS VALUE
GRID-LEAK
GRID CONDENSER
GRID WILL TRAP ONLY HALF AS MANY ELECTRONS SO WILL HAVE ONLY HALF PREVIOUS AVERAGE NEGATIVE CHARGE. SO PLATE CURRENT WILL BE DECREASED HALF AS MUCH
PLATE CURRENT IN TELEPHONE RECEIVER THEREFORE DEPENDS ON INTENSITY OF RAPID RADIO WAVES AS INTENSITY OF WAVES IS CONTROLLED BY VOICE AT RADIO TRANSMITTER, TELEPHONE RECEIVER WILL HEAR THIS VOICE.

Half Strength Waves

are trapped. This means that the average plate current will be correspondingly decreased, and the telephones will note this.

Now that the telephones have noted it, it is necessary to bring the grid back to its original condition if the oscillations in the antenna have stopped. This is done by means of the grid leak.

Grid Leak. The grid leak consists of a very high resistance of about one million ohms. This resistance is very easily made. Some India ink on a strip of cardboard half an inch long by an eighth of an inch wide will have a resistance of this order.

This resistance is put directly around the small grid condenser. It allows the trapped electrons to get from the grid-condenser lead out into the set. The resistance is made very high, though, so that they will do this quite slowly compared to the oscillations in the tuner. But they will do it fast enough to correspond to the changes in intensity which correspond to sound. So, if there is a peak of radio wave intensity corresponding to the peak of a sound wave at the transmitting station, the plate currents in the tube will be correspondingly depressed by the trapped electrons. As the ether waves decrease in intensity, corresponding to a dip in the sound waves at the transmitting station, the trapped electrons will leak out through the grid leak, the grid will return to its normal value, and the plate current will come back. So the telephones will work in and out to correspond to the sound waves at the

transmitting stations, and will reproduce the music.

Naturally, it is possible to add transformers and amplifier tubes to the detector tube in exactly the same manner as they were for the crystal detector, to increase the intensity of the received signals. It is usually advisable to have separate filament rheostats for detector and amplifier tubes, however.

Ballast Tubes. In place of rheostats, ballast tubes may be used. A ballast tube is one which will hold the current which passes through it to a pretty constant value regardless of the voltage which may be applied. These ballast tubes consist usually of an iron wire filament in a tube filled with hydrogen. The filament is heated to such a low point that it can be hardly noticed. The resistance of this iron wire in the hydrogen increases greatly with heat. So if extra voltage is put on it, the iron wire tends to heat up, and the resistance increases proportionately. With more resistance, the current is held to approximately its first value. This device takes up the variation of storage batteries as they discharge.

XVII

FEED–BACK

"We but teach
Bloody instructions, which, being taught,
return
To plague the inventor."

—MACBETH.

HOWLING of vacuum tube amplifiers has been already spoken about. It happens too readily nowadays. But when the first imperfect tubes were made, it took an inventor like E. H. Armstrong to discover this principle of feeding some of the energy of the plate back into the grid. But he did it with discretion so that the effectiveness of the tube was much increased by the process.

To realize this action, all that is necessary is an additional small coil of some ten to twenty turns in the plate circuit of a detector tube. Either the gas tube or the grid leak-condenser detector tube may be used.

The plate current follows the rapid frequency variations in step with the oscillations in the radio tuner. Therefore, the small coil in the plate

circuit will follow these variations also. The plate coil is then brought near to the tuner coil. This makes a transformer out of the combination with the plate coil as the primary and the tuner coil as the secondary. If the two coils have their turns in such a direction that by transformer action an increase in the plate coil current makes an increase in the tuner coil, the feed-back principle will be realized.

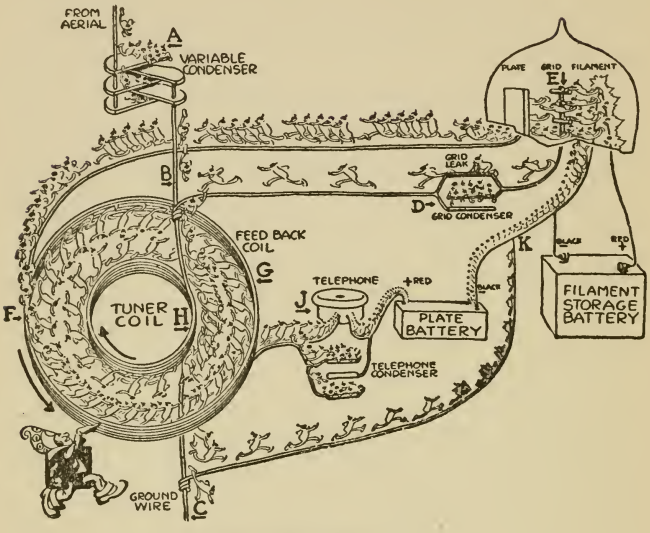
If this reaction is carried to the limit, oscillations will be produced at the high frequency for which the tuner is set. This reaction should be decreased below this value by decreasing the "coupling" or the reaction between the two coils. This may be done conveniently by moving the plate coil away from the tuner coil, or by decreasing the number of turns used in the plate coil. When the coupling is so reduced, the outfit will not oscillate of itself, but if any effect comes in on the grid of the detector tube, it will be amplified by the tube and fed back on to the grid to be reamplified so that the total amplification may be fifteen times the original. The detection action goes on exactly as before. It merely means that the arrangement is such that with a little shove from the incoming energy, quite a large motion will result in the plate current.

Amplifier tubes with the necessary transformers may be added to this feed-back circuit as well.

Caution! It must be realized that the feed-back circuit in the oscillating condition makes a generator out of the receiving station and antenna when using the single circuit tuner which has been described. In this condition, sensitive receivers within an eighth of a mile will pick up these generated waves. If these waves are just a little different than the incoming waves of a broadcast transmitter, the two will "beat" with each other, giving the familiar squeak-squak that will completely spoil the reception both at the guilty receiving station and everywhere else in the vicinity. "Courtesy of the ether" should reduce this interference.

Of course, this beat tone makes a very powerful method of picking up weak signals. With the feed-back, or "tickler" in the oscillating condition, weak signals will be heard as this beat tone when the tuner is adjusted nearly to the wave length of incoming signals. As the tuning is made more accurate, the pitch of this beat note will become very low, finally reaching a point where it disappears altogether. This setting is called working on the "zero beat note." It is not to be recommended, though, as any slight variation in either the transmitted wave length or the receiver setting will bring in the note again. It is better to use this method if necessary to locate the signals, and then to tune more sharply and

reduce the "tickler" to the point where the set just does not oscillate.



COMPLETE FEED-BACK ACTION

Oncoming ether wave forces electrons from A down through B around tuner coil H out C to ground. This draws electrons from grid E through grid leak-condenser D to B. This allows more electrons to rush across tube at E to plate and through wire to left around feed-back coil at F. By transformer action this reacts on tuner coil H to increase original electron flow. This increased flow acts back through same process so that plate current is carried immediately to the limits of amplification. Grid leak-condenser at D acts to make grid quite negative which decreases average current through telephone receiver J. Batteries force the electrons around the circuits joined at point K back to the filament of the tube.

XVIII

DOUBLE CIRCUIT TUNERS

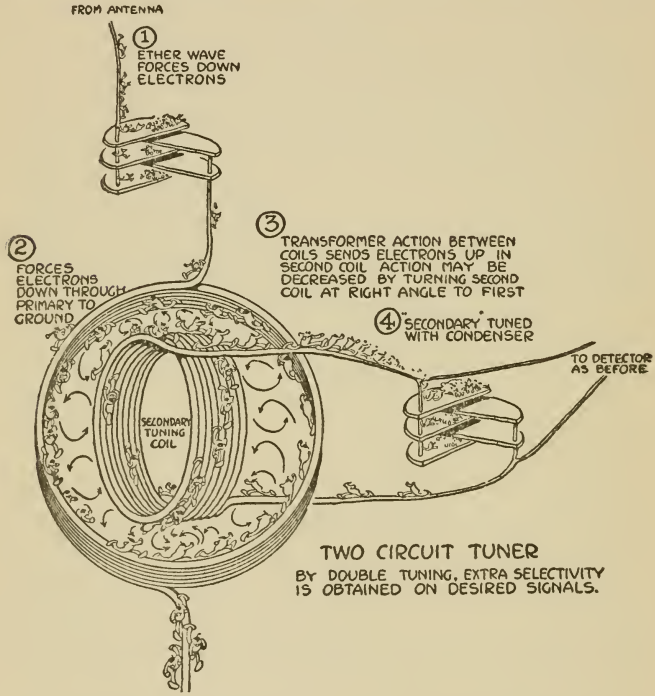
"Then Heaven tries Earth if it be in tune."
—LOWELL.

TO GET much sharper tuning in radio receivers double circuit tuners are excellent. The double circuit tuner is more complicated, but after the radio-fan has become expert in handling everything up to this point, he may well try the double tuning to reduce interference from other wave lengths as well as static.

This tuner will be readily understood now. It consists essentially of two tuned circuits. The first is exactly the same as the one first described on page 54. But instead of tapping its energy across the tuning condenser or coil, the energy in the tuned circuit is transferred on into another circuit. This is done by arranging the two coils of the two circuits as a transformer. It is usual to make one coil rotatable with respect to the other, so that the amount of transformer action or the "coupling" may be controlled by the operator. The first tuning system is called the primary

circuit, and the second is naturally called the secondary tuned circuit.

The secondary circuit consists of a tuning coil with a tuning condenser directly across it. This


FROM ANTENNA
1 ETHER WAVE FORCES DOWN ELECTRONS
2 FORCES ELECTRONS DOWN THROUGH PRIMARY TO GROUND
3 TRANSFORMER ACTION BETWEEN COILS SENDS ELECTRONS UP IN SECOND COIL ACTION MAY BE DECREASED BY TURNING SECOND COIL AT RIGHT ANGLE TO FIRST
4 SECONDARY TUNED WITH CONDENSER
TO DETECTOR AS BEFORE
SECONDARY TUNING COIL
TWO CIRCUIT TUNER
BY DOUBLE TUNING, EXTRA SELECTIVITY IS OBTAINED ON DESIRED SIGNALS.

second circuit oscillates exactly as did the antenna set and ground. Energy in the coil surges into the condenser and then reacts back, with a swinging motion. The tuning to a particular wave

length is accomplished by varying either the number of turns in the coil or the value of the condenser or both, in the secondary circuit.

Connection to Detector. The primary circuit only furnishes energy to the secondary. The secondary furnishes the energy to the detector. Two points which develop maximum differences in electron concentration, or voltage, are the two sides of the secondary condenser. If one lead is taken from one side of the condenser to the grid of a gas tube, for example, and the other side of the condenser is connected to the filament, the gas tube will detect the surges in the secondary circuit.

Adjustment of Two Circuit Turners. Adjustment of two circuit turners will give little difficulty if the coupling between the primary and the secondary is made very "tight" or close when starting. Naturally, both primary and secondary must be adjusted together until the desired signals are heard. With a little practice, the general settings of the primary and secondary which correspond will be found.

When the desired signals are obtained, the coupling is reduced slightly, and the two circuits retuned to be sharply on the signal. The process of decreasing the coupling and retuning is continued until the desired degree of selectivity is reached. The intensity of the signals will go down slightly as the coupling is reduced, but close tuning will

bring it up very near the original value. The secondary tuning will usually be much sharper than the primary. This is because the antenna and ground system usually have more resistance, which dulls the primary tuning.

If the primary tuning is very broad, it is a sure sign that the resistance of the antenna-ground system is higher than it should be. The insulators supporting the antenna should be investigated for leakage to ground. And a better ground connection for the set may be necessary.

Feed-Back on Two Circuit Tuners. The feed-back may be applied to double circuit tuners very readily. There is the distinct advantage to these tuners for this work in that with loose coupling the set will not radiate hardly any oscillations due to the feed-back in the oscillating condition. This oscillating energy will be practically all confined to the secondary circuit. This is due to the fact that the primary circuit will be tuned directly to the signals, whereas the secondary will be slightly off tune in order to produce the oscillations at a slightly different frequency to give the beat note. Of course, both will be on the signal frequency with the zero beat condition. The quality of the signals on the zero beat condition is nowhere near as good as it is on straight detection, however, so this condition is not recommended for any but the weakest signals.

XIX

LOUD SPEAKERS

"*Brutish noises are bellow'd out,*
And cracke the barbarous voices."

—ILIAD.

CHIEF among the aims of the radio-fan is the desire to be able to have a loud speaker that will give real entertainment to a roomful of friends, and it requires his full skill to accomplish this.

The very best apparatus available requires sympathetic adjustment to produce good results.

Receivers in Series. One of the simplest answers to provide entertainment for more than one is the use of more than one head-set at the same time. This may be done by placing the head-sets in series on the output of whatever set is used. To put them in series means that the electric current output of the radio set must pass through each head-set in succession. A convenient way to arrange this is to put each head-set on a plug of its own, and then to arrange a group of two or three jacks to plug them in to. These jacks may be bought and mounted in a row in a small wooden

box. The type of jack which should be bought is that which has a second spring on it which makes contact with the tip spring when there is no plug in the jack. The tip spring is pushed away from this second spring when the tip of the plug is pushed under it. This extra spring and the base of the jack which makes contact with the sleeve of the plug when the latter is inserted must be joined together by a wire on each jack. The wire which is used to do this in each case is extended on to the tip spring of the next plug. The last such wire connects directly to the output of the set. The other connection to the set is made from the tip spring of the first jack.

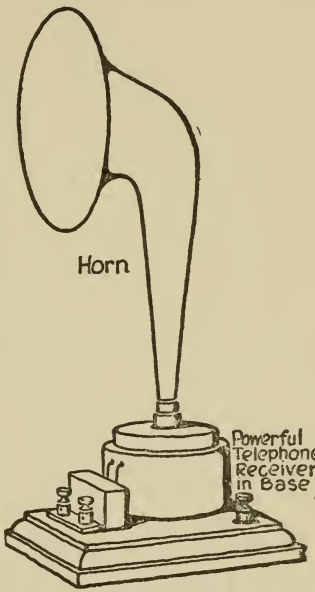
Now if there are no plugs inserted in the box full of jacks, the telephone currents from the set will pass through one jack after the other and back into the set. To hear them, a head-set plug is inserted in one of the jacks. This opens the contact at that particular jack between the tip and the extra spring, but the plug itself completes the circuit between the tip and sleeve of the inserted plug, which is connected to the telephone receivers of the head-set. When other head-sets are "plugged in," they, too, will get in the circuit, and hear the telephone currents which are produced by the radio set.

This method of connecting two or even three head-sets to a radio set will give very satisfactory

results, particularly on distant stations; also the quality of the signals will be excellent.

For those who do not like to wear the head-sets the loud speaker is the real answer.

Types of Loud Speakers. There are almost as many types of loud speakers as there are radio manufacturers, so it would be hopeless to try to describe them all. Their very number indicates that there may be a wide divergence in their performance and their service.



A Loud Speaker

The two essentials of a loud speaker are: First, a good telephone receiver, and second, a good horn. The telephone receiver has a tremendous amount of influence on the character of the loud speaker. It should be able to handle pretty high telephone currents without distorting them horribly. It is basically the same receiver as that of the head-set. As it is usually necessary to have rather high currents for loud speaker work, great care should be

used to see that the current is in such a direction as to increase the permanent magnetism of the receiver from the amplifier set.

If the telephone receiver rattles, it is because the thin iron diaphragm of the receiver is hitting the pole pieces of the receiver as the diaphragm moves in and out. To remedy this, tighten the cap of the receiver as suggested before, or if this is not sufficient, put in a paper washer between the base of the receiver and the diaphragm, as was described in the chapter on the receiver.

Extra Powerful Telephone Receivers. For loud speaker work extra powerful telephone receivers are made. One type of these has a lever arrangement which with a small movement caused by the magnetism of the coils moves the diaphragm back and forth at the end of the lever arm to a much greater extent. The diaphragm for these receivers may be of any material that will vibrate well. Mica and bakelite have been used for this.

Another type has two separate coil circuits in the receiver. One of these coil circuits has for its purpose the furnishing of the permanent magnetism in place of a permanent steel magnet. The permanent magnetism is obtained from a larger coil, energized by a storage battery. A small coil is then used to handle the telephone currents from the radio set, but this second coil is usually mounted directly on the diaphragm, which may be

of any vibrating material. This small coil then becomes a magnet with the telephone currents which pass through it, and is attracted more or less to the fixed magnet in the base of the receiver.

The Horn. The horn takes the output of the radio receiver and sends it into the room. The horn must not have a metallic tone of its own, as it would then vibrate to this tone whenever the music happened to contain it, and this would give undue prominence to such a tone. Short metal horns have such high, free tones of their own that there is less danger of this. For the larger horns, a deader material is necessary. Some of these are: papier maché, wood, lead, parchment, and other compounds.

The phonograph art has gone through this same stage quite completely, and one simple answer is to use a phonograph cabinet. Loud speakers are built of this design, or attachments are on sale which will make any telephone receiver serviceable to attach to an ordinary phonograph.

Solid Support. Vibrations of the loud speaker should be avoided by placing it on a solid foundation, as upon a solid block of wood, metal, or marble, which help in this respect.

Amplifier Adjustment. By trial, it will soon be found that the filament heating of the amplifier tubes has a large effect on the quality of the loud speaker output. If the filaments are too low, the

telephone currents will be broken up. If the filaments are too high, the tone will be muffled. The best position will be found between these limits, and then if a feed-back connection is used on the detector tube, care must be taken that this feed-back action is not too strong. If there is a steady hum to the radio transmitter, this may be reduced at the receiving station by detuning the set slightly from the maximum position.

It is only with extra power, full transmission, and unusually favourable conduction, that results should be expected from loud speakers at distances over sixty miles from the transmitter. This limit may be passed, but has not been consistently exceeded as yet.

XX

BATTERY FORCES

"Powers that will work for thee; air, earth, and skies."

—WORDSWORTH.

UNFORTUNATELY, vacuum tubes require power to drive them. First, it takes power to light the filaments, and second, it takes power to pull the little electrons from the filaments to the plate in the tube.

Filament Batteries. Usually, storage batteries are necessary to light the filament. Storage batteries consist of metal plates in a chemical solution. The solution will generate electricity by its action on the plates of the battery. The eating of the plates by the solution causes a re-arrangement of the electrons from their average density, giving zero charge, such that there is a concentration of them on one of the plates and a diminution on the other. This gives rise to the desired electric potential or pressure. If a wire connects these two opposite plates through some electric apparatus, this excess of electrons on one plate will have a

chance to run to the one with less. This motion of the electrons through the connecting wire and apparatus does the necessary work, and relieves the electric potential between the plates which was developed by the chemical action. Before the wire is connected, the chemical action could only go so far as to produce this stress and then stop—but now that the stress is relieved by the connection, the chemical action will continue as long as the energy is used.

Composition of Storage Batteries. The two principal types of storage batteries are, first, the lead batteries, and second, the alkali batteries. In either of these batteries there are two sets of plates in each cell and a solution which will act on these plates. As the solution acts on the plates to produce electricity, the chemical strength of the solution decreases. Finally, a point is reached in this discharge beyond which it is not wise to go without danger of permanent harm to the battery. It is then necessary to re-charge the battery.

Re-charging consists in sending an electric current back into the battery in the reverse direction from that in which it was taken out. It is natural to understand that this process of forcing electrons the other way would give back to the battery the chemical strength which was lost in sending electrons in the first direction. This process of charge and discharge may be repeated until the plates

begin to disintegrate under the continued building up and knocking down of their surface by the electric charging current on the one hand and the chemical eating away on the other.

The re-charging of the batteries is done by means of a direct current from a power supply. It may well be asked, that if the battery is discharged and then re-charged from a power supply, why is not the power supply used directly in the first place? The reason is that the power supply is not generally smooth enough not to cause noise by its changes in the vacuum tube filaments. There are means for using the power supply directly for lighting vacuum tube filaments, but they require special adjustments and transformers, which mean just one more complication to the already pretty complicated radio system; so the radio-fan will do well to get the radio set to work well with the very smoothest battery supply taken from storage batteries.

Battery Capacity. A lead plate battery, with two sets of plates in a sulphuric acid solution, will develop about two volts of electric pressure. The number of amperes of current that it will deliver at this pressure is determined by the size of the plates. The larger the plates, the more amperes of current there are available. To indicate this, batteries are rated in terms of their ampere-hours capacity. For example, an eighty ampere-hour

battery will deliver one ampere for eighty hours, or two amperes for forty hours, etc.

Vacuum tubes usually take more than two volts to get the necessary current through the resistance of the filament. For this reason, it is necessary to combine several cells in a single battery. Each cell will give two volts pressure, so a six-volt battery is made up of three cells in series. These are placed in series by having the plate terminal of one, which develops the excess of electrons, connected to the plate of the next cell which has the shortage. This excess on the one plate will balance the shortage in the second battery, so that its negative pole will then be able to go to twice the excess or negative that it had before. Likewise, the third cell is connected so that the three will have six volts of pressure in series.

The alkali batteries, such as the "Edison," only develop 1.2 volts per cell, so that it takes more of them to make the necessary voltage, but they are much lighter.

Care of Storage Batteries. The installation of the storage battery has been given on page 43. Fortunately, for the radio fan, the automobile industry has already developed storage batteries to a high state of efficiency, so if he buys a standard make there need be little worry about its care. These are the principal points.

(1) The battery should be kept clean.

(2) The solution should never get below the tops of the plates.
(3) The solution should be kept up to strength.
(4) The battery should be regularly charged.
(5) If anything irregular develops in the performance of the battery, it should be taken at once to a battery expert.

Neatness. Particularly during the charging of storage batteries, there is a bubbling of the solution which may cover the tops of the jars and the connections. These should therefore be wiped clean with some waste or cloth moistened with ammonia water. The use of vaseline under the connecting joints is recommended to keep out the action of the acid at these points. No metal should be exposed to the action of these battery fumes, except lead. If the battery is enclosed in a wooden box, the box should be painted thoroughly, particularly at the joints, with two coats of asphaltum.

Height of Solution. With evaporation and bubbling during charging, the battery will lose water. This should be made up by adding distilled water, so that the tops of the plates are covered. If the water comes to the bottoms of the filling tubes in the cells, this indicates that there is sufficient water.

Distilled water must be used, as ordinary water contains salts which added to the battery solution

will decrease its efficiency. Distilled water may be obtained by melting snow or artificial ice, or from fresh rain water. It should be kept in a covered glass or porcelain vessel, as it will otherwise pick up impurities. Water should always be added to the battery before charging, instead of afterward, so that the charging will thoroughly mix it. For alkali batteries, fresh distilled water is best.

Strength of Solution. The stronger the solution, the heavier it is. An instrument called a "hydrometer," indicates this. By means of the syringe attached to the hydrometer, some of the solution may be drawn into the glass tube of the hydrometer. Like salt buoys up swimmers in the ocean, so the strength of the solution buoys up the little float in the hydrometer. The higher the float rises above the level of the solution in the hydrometer, the higher its scale indicates directly the strength of the solution.

The strength of the solution is a direct indication of the amount of the electric charge in the lead battery. A table showing this follows:

CONDITION	VOLTAGE PER CELL	DENSITY
Charged	2.2	1.260–1.280
Service	2.0	1.225
Discharged	1.8	1.175

Regular Charging. It is not a good plan to let the battery get to the lowest possible point before re-charging. It is far better to keep it charged regularly. Its voltage and value will then not change appreciably, which will mean that the controls on the tubes may be kept constant at one adjustment.

For re-charging, a power attachment is necessary. The type of attachment depends upon the kind of lighting current in the house. It takes direct current to charge a battery. If the house lighting is direct, all that it is necessary to do is to have a means of controlling the strength of this direct current when it is connected to a battery.

Direct Current Power Supply. The ordinary electric light mains supply 110 volts to single lights. It takes only ten volts to charge an eight-volt battery. Some resistance must be inserted in the connection between the power supply and the battery for charging. These resistances must be able to take care of the amperes of current that are wanted to charge the battery. For an 80-ampere hour battery, it would be six amperes. For a 40-ampere hour battery it would be three amperes. Other sizes would be proportional to these.

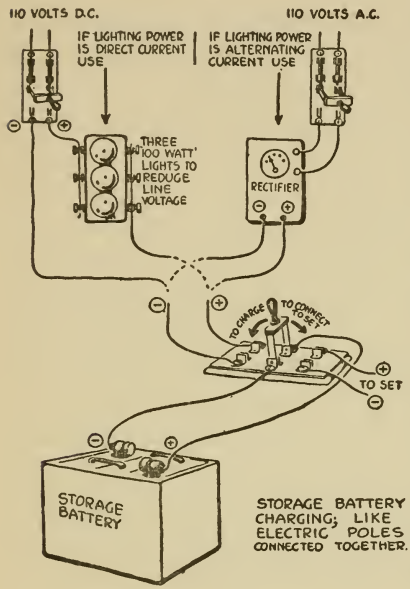
A resistance, to use up 100 of the 110 volts, to bring it down to 10 volts for charging at the six-ampere hour rate, would have to have a resistance of 16 ohms. If it was to charge only at the three-

ampere rate, its resistance would have to be twice as much, or 32 ohms. The way to find this out for any particular value is to use what is called "Ohm's law." The necessary resistance will be equal to the voltage drop or loss required, divided by the amperes required. For example, for 100 volts drop with five amperes this would be 100 divided by 5, or twenty ohms.

Resistances are on the market for this purpose, but electric lights may be used for the same purpose. A 100-watt lamp is one that lets one ampere through at 100 volts pressure. This means that it has a resistance of 100 ohms. If one such lamp is put in a series between the lighting power and the storage battery it will let through one ampere into the battery. If two such lights are used in parallel, they will make two paths for the power current to get through to the battery, which will mean two amperes into the battery. Three lights in parallel would mean three amperes, and so on.

Direction of Charge. A very important precaution is the direction in which the charging is done. In order to recharge a battery, the electrons must be sent back into the battery in the reverse direction to which they came out. They came out of the negative terminal, naturally; so they must be sent back that way. To do this, the negative terminal of the power supply must be connected to the negative terminal of the battery, and of

course this leaves the positive terminal of the battery to be connected to the positive wire of the power supply. In other words, for charging, like terminal is connected to like terminal, and the one with the greater power will send current through the other. Of course the lighting circuit has the greater power.


110 VOLTS D.C.
110 VOLTS A.C.
IF LIGHTING POWER IS DIRECT CURRENT USE
IF LIGHTING POWER IS ALTERNATING CURRENT USE
THREE 100 WATT LIGHTS TO REDUCE LINE VOLTAGE
RECTIFIER
TO CHARGE
TO CONNECT TO SET
TO SET
STORAGE BATTERY
STORAGE BATTERY CHARGING; LIKE ELECTRIC POLES CONNECTED TOGETHER.

A ready means of identifying the negative terminals of both the battery and the power supply is to use a glass filled with water, and a drop or two of the sulphuric-acid solution. If two wires are led from the source to be determined, bubbles will come off the negative one very rapidly. This may be remembered by considering that this represents the electrons breaking loose on the negative wire. In making this test, care must be used that the two wires are not allowed to touch each other in the

solution, otherwise a bad short circuit may result.

To protect the battery and circuit, fuses should be provided in both wire leads from the power supply. The connection should be as follows: From the two 110-volt power supply sides are taken two wires to two fuses. These should be 15-ampere fuses. From the fuse is connected a double-pole single-throw switch. Next, the two sides of the switch should be tested for their polarity, with the glass of water. The negative one is then connected directly to the negative pole of the storage battery with a "bull-dog" clip. The positive lead is taken through one, two, or three 100-watt electric lights in parallel. The far side of these lights is then connected to the positive terminal of the battery.

Charging. It is well to start the charging at a good rate, and then to decrease the rate toward the end. This can be done readily by unscrewing some of the lights to decrease the charging current. This is called giving the battery a "tapering charge." The battery will be charged when the cells are bubbling freely. The hydrometer will show that acid cells have reached their maximum strength of solution by no further increase of density. This maximum is about 1.280. The filling stoppers in the battery should not be out during charging. They will keep in the sputtering

of the bubbles in the solution. Acid batteries will have longer life if the density of the solution is only carried to 1.260. Frequent charging at a low rate is the best answer.

Alkali batteries can only be tested for charge with a voltmeter. One volt per cell indicates complete discharge. Its average voltage per cell is 1.2 during service; and the full charge value is 1.5 volts. Alkali batteries have a good feature in that overcharge unless too hot and discharge have no serious effect on them.

Another way to tell whether battery cells are connected to the power supply in the right direction is by observing the lights. They will be much brighter if they are connected the wrong way to the battery than if they are connected correctly so that they are doing the necessary charging work which diminishes the light.

Alternating Current Supply. If only alternating current is available for the charging of the storage batteries, a rectifier must be used. One such rectifier uses vacuum tubes, built, however, to handle much larger currents. These rectifiers are marked to indicate which are the positive and negative output terminals, to be connected respectively to the positive and negative terminals of the battery. A spare tube should be obtained with these sets, as they, too, burn out, unfortunately.

Another type of rectifier is the vibrator. This acts as a buzzer, which switches the currents into the battery on one-half of each cycle of the alternating currents. This, of course, lets through the current in only one direction to the battery, which thereby corresponds to direct current. Some of these vibrators or rectifiers are so arranged that they will send current in the right direction into the battery whichever way the battery is connected.

With the tube and vibrator types of rectifier it is well to insert adjustable resistances in the lead from the rectifier to the battery. If the battery is quite low at the start, there will be too great a rush of current from the rectifier to the battery, which may damage both. This resistance may consist of 100-watt lights between the rectifier and the battery, or it may better be an adjustable rheostat that will carry say eight amperes. This resistance should be able to give a maximum of one ohm.

As the extra refinement in battery charging it is excellent to have an ammeter to measure the current flow in the battery. This indicates very clearly just what is going on in the battery, and will show if the current is going in the right direction.

Irregularities. If the battery acts in any way abnormally, it is a sure sign that something is wrong. If one cell takes much longer to charge

than the rest, there is usually something wrong with that cell. It may be short-circuiting inside. If one cell loses solution faster than the rest, there may be a leak in the container. In either event, the cell should be taken to a battery expert for repair.

It is always well to keep a battery charged, even if it is not to be used at once. If a battery is not used for six months, it should be given a charge at the expiration of that time. Nothing but water should ever be put in a battery, except by the battery expert. In charging, the battery should not rise to a temperature above 110 degrees Fahrenheit. The charging is done too rapidly if it does.

Caution. No battery should be left connected to a radio receiving set while it is being charged. First, if it is left connected to the set, this may ground one side of the battery, and as the direct current supply is always grounded, a bad short circuit may result. Second, the battery will be at a higher voltage as it is being charged, and this might burn out the tubes of the set. Third, the charger will bring in considerable noise to the set, unless filters are provided.

Double-Throw Switch. A good way to connect the battery first to the charger and then to the set is to provide a second switch, which should be a double-pole, double-throw switch. The battery

is connected to the middle two blades of the switch, and the two connections on one side of the switch are lead to the charging outfit, and those on the other side of the switch are led to the set. Now, when the switch is thrown in one position, the battery is directly connected to the charger; and it is connected to the set when thrown the other way. Naturally, care must be taken that the battery polarities of positive and negative are connected correctly in both cases.

Plate Batteries. The other battery power necessary for running tube detector sets is the plate battery. These are usually made up of several cells of dry batteries connected in series. As pointed out before, only small current values are necessary for the plate battery. A dry battery is one in which there are two substances, acted on by some solution between; but the solution is made in the form of a wet paste so that it will not spill. These batteries are made in units of $22\frac{1}{2}$ volts, and larger sizes. They should be kept in a cool place, which will lengthen their life. Once a dry battery goes bad, there is very little that can be done for it except to buy a new one.

Noisy Batteries. If a set becomes noisy, in addition to the effect of static, it is pretty certain that the trouble is with the batteries. The connections should be gone over to see that they are tight, then if the noise continues, it is a pretty sure

sign that the plate battery is no longer any good. The antenna should be disconnected from the set, to be sure that the noise is not from the outside.

Dry Batteries for Filaments. The only reason that dry batteries may not be used for lighting the filaments is that they do not supply enough current. However, there are now vacuum tubes on the market which will work on much less current, and these will work from dry cells. But these cells are different from those that are used for plate batteries, in that they are designed to give much more current at a lower voltage. Single cells are usual, each of which gives $1\frac{1}{2}$ volts pressure. Enough such cells are put in series to give the voltage required by the tube, as shown on its box. Some tubes require but one cell.

Great care must be taken that the plate battery is never connected to the filament battery terminals. The results will be disastrous, both to the batteries and to the tubes in the set. The plate battery will supply sufficient current for the short time it takes to burn out the filaments of the tubes connected. For this reason, it is always a good plan to connect the filament battery before the plate battery. If the filaments light correctly off the filament battery, the plate battery may then be connected, with no fear of burning out the tubes.

Batteries are the main force behind the radio receiver, and the radio fan should know how to conserve these battery forces, to get good signals at low cost, that will make his efforts worth while.

THE END

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